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EXHAUST EMISSION SURVEILLANCE OF ONTARIO IN-USE CARS (FULL REPORT)

PART 1: TEXT

OCTOBER 1988

Environment
Ontario

Jim Bradley
Minister

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Exhaust Emission Surveillance of Ontario In-use Cars

(FULL REPORT)

Part I: TEXT

by

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Abstract

Exhaust emissions (HC, CO, CO_2, NO_x) from 372 in-use, gasoline-powered, light-duty vehicles (1962/84 MY) were measured with the following objectives: to characterize Ontario 1982 car population, to establish a data base for generating emission factors, to estimate compliance with Ontario criteria and Canada standards, and to establish correlation between cold-start federal test procedure (FTP-75), modified hot-start procedure (MFTP-75) and the Ontario Idles Test. Vehicles were sampled on a voluntary basis from the Greater Metro Toronto area, mostly from private owners (unsafe and smoking vehicles were excluded). Cars were tested in as-received condition using owner-supplied gasoline.

A sample of 200 cars (OS 200), representing the sales-weighted car population of mid-1982, indicates that 48% of cars fail one or more of the four Ontario criteria (for HC and CO in Idle and Fast Idle). Almost three-quarters (74%) of the cars fail one or more of the Canada standards (HC, CO, NO_x).

Excessive emitters, estimated at 15%, are likely responsible for almost half of the HC and CO emissions from cars.

The Ontario Idles Test predicts the compliance with Canada standards very well. Also, it identifies 90% of excessive emitters. The shorter hot-start MFTP correlates very closely with the 2-day cold-start FTP.

Included are results of 2 propane-powered cars and a summary of Ontario emission control programs (1969-84), description of test facilities, and of vehicle selection, acquisition and data evaluation procedures.

Résumé

Nous avons mesuré les gaz d'échappement (HC, CO, CO_2, NO_X), produits par 372 véhicules légers en cours d'utilisation et propulsés à l'essence (construits entre 1962 et 1984), avec les objectifs suivants : dégager les caractéristiques du parc automobile ontarien en 1982, créer une base de données sur les origines des émanations, déterminer la conformité avec les critères ontariens et les normes canadiennes, et établir une corrélation entre le test fédéral de démarrage à froid (FTP-75), le test modifié de démarrage à chaud (MFTP-75) et le Ontario Idles Test (test ontarien des ralentis). Des propriétaires de véhicules - pour la plupart des particuliers - habitant l'agglomération torontoise se sont portés volontaires (nous avons exclu les véhicules dangereux et ceux qui dégageaient de la fumée). Les véhicules ont été testés dans l'état dans lequel ils ont été présentés, avec l'essence fournie par le propriétaire.

Un échantillon de 200 véhicules (OS 200), représentant le parc de véhicules vendus à la mi-1982, indique que 48 p. 100 des véhicules ne satisfont pas à un ou plusieurs des quatre critères ontariens (HC et CO en ralenti et ralenti accéléré). Presque les trois quarts (74 p. 100) des véhicules ne satisfont pas à une ou plusieurs des normes canadiennes (HC, CO, NO_X).

Des émetteurs - estimés à 15 p. 100 - provoquant un dégagement excessif sont vraisemblablement responsables de presque la moitié des émissions de HC et de CO.

Le Ontario Idles Test permet de prévoir la conformité avec les normes canadiennes. Il identifie également 90 p. 100 des émetteurs provoquant un dégagement excessif. Le test modifié de démarrage à chaud (MFTP), plus bref, est lié très étroitement avec le test de démarrage à froid (FTP) d'une durée de deux jours.

Le rapport comprend également les résultats obtenus avec deux véhicules mus au propane et un résumé des programmes de contrôle des émissions en Ontario (1969-1984), une description des installations utilisées pour les tests, les modalités de sélection et d'acquisition des véhicules ainsi que les techniques d'évaluation des données.

TABLE OF CONTENTS

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Page

Abstract i
Table of Contents ii
List of Tables iv
List of Figures viii
Acknowledgements xi
Abbreviations, Symbols and Conversions xii

1.0 EXECUTIVE SUMMARY 1

2.0 INTRODUCTION 3
- 2.1 Background and Chronology 3
- 2.2 U.S., Canada and Ontario Emission Standards 8
- 2.3 EPA Emission Factor Test Programs 12
- 2.4 Environment Canada Emission Test Programs 14
- 2.5 Ontario Emission Test Programs 15

3.0 TEST PROGRAM OBJECTIVES and DESIGN 20
- 3.1 Test Program Objectives 20
- 3.2 Test Program Design 21

4.0 TEST VEHICLE SELECTION 23
- 4.1 Vehicle Population Data 23
- 4.2 Size of Representative Sample 30
- 4.3 Sample Selection Procedures and Criteria 35
- 4.4 Target List 200 41

5.0 VEHICLE ACQUISITION and TEST FLEETS 42
- 5.1 Soliciting and Incentives 42
- 5.2 Handling 43
- 5.3 Insurance 46
- 5.4 Test Fleets A - D 46

6.0 TEST FACILITIES 48
- 6.1 Locations and Lay-out 48
- 6.2 Chassis Dynamometer 51
- 6.3 Constant Volume Sampler - CVS 51
- 6.4 Emission Analysis Console 52
- 6.5 Calibration Gases and Quality Assurance 54
- 6.6 Computer and Auxiliary Equipment 61

Page

7.0 TEST PROCEDURES 63
7.1 Idles Test 63
7.2 Preparation and Preconditioning 63
7.3 FTP-75 Test (Cold-start, EPA Urban, 3-bag test) 64
7.4 MFTP-75 Test (Hot-start, DYN 9, 2-bag test) 65

8.0 DATA COLLECTION and EVALUATION PROCEDURES 67
8.1 Collection and Handling of Data 67
8.2 Calculation of Results 67
8.3 Data Processing 68
8.4 Statistical Analysis System (SAS) 68
8.5 SAS Variables and Coding 70

9.0 TEST DATA (by Fleet) 75
9.1 Fleet A: Wider Ontario Sample - 295 75
9.2 Fleet B: Ontario Sample - 200 79
9.3 Fleet C: High-mileage Government Cars 82
9.4 Other Test Data (Fleet D & Retests) 84

10.0 DICUSSION OF TEST RESULTS 88
10.1 Fleet A: WOS 295 88
10.2 Excessive Emitters (in WOS 295) 113
10.3 Fleet B: OS 200 118
10.4 Fleet C: Police & Gov't Cars 126
10.5 Other Test Data 127

11.0 CONCLUSIONS and RECOMMENDATIONS 129
11.1 Conclusions 129
11.2 General Outlook 131
11.3 Recommendations 132

12.0 REFERENCES 133

13.0 APPENDICES Part II

LIST OF TABLES

Table	Title	Page
2.1-1	Contribution of Transportation Sources to Total Emissions in Ontario	4
2.1-2	Ratios of Canada/U.S. Exhaust Emission Standards	5
2.2-1	LD - Vehicle Exhaust Emission Standards (or equivalent levels) in U.S., Canada and Ontario	10
2.3-1	EPA Emission Factor Testing Programs for Light-duty Vehicles (cars and light trucks)	13
2.4-1	Environment Canada Test Programs	15
2.5-1	Ontario Spot-checking Programs by Test Year and Test Type	18
2.5-2	Ontario Mass-emission Surveillance Program by Test Year and Car Owner	19
4.1-1	Ontario Motor Vehicle Registration (in 000's)	25
4.1-2	Ontario Passenger Car Registrations by Cylinders (% of relative frequency)	26
4.1-3	New Vehicle Registrations and Sales in Ontario (in 000's) by Calendar Year and Vehicle Category	27
4.1-4	Data on Average Age Distribution in U.S. and Ontario Car Populations	28
4.1-5	Simple (1-year) and Compounded Survival Factors for Cars (U.S. data for 1962-73 calendar years)	30
4.2-1	Calculation of Sample Size n (based on data from 12 cars)	33
4.2-2	Sample Sizes Used by EPA during 1975, 1977 and 1979 FY Surveillance Programs	34
4.3-1	Ontario New Car Registration by Models (1978-81)	APP.A1
4.3-2	Car Sizes by GVW	36
4.3-3	Ontario New Car Registrations (1968-81)	38
4.3-4	Preferred Mileage Ranges of Target Cars (by MY and CID)	39

Table	Title	Page
4.3-5	Basic Specifications for Target List 200	40
4.4-1	Target List 200 (Ontario population as of mid-1982)	APP.A2-6
5.1-1	Rental Fee Structure ($ per 2-day test)	43
6.5-1	Lowest Coefficients of Variation (C.V.) in Repetitive MFTP-75 Tests (8 series, 4 cars)	60
7.3-1	FTP-75 (EPA Urban Test)	64
7.4-1	MFTP-75 (Two-Bag Test)	66
9.1-1A	WOS 295 List by TEST CAR - Part A	APP.C1-7
9.1-1B	WOS 295 List by TEST CAR - Part B	APP.C8-14
9.1-2A	WOS 295 Characteristics of Fleet A	76
9.1-2B	WOS 295 Sample Characteristics	APP.C15-16
9.1-3	WOS 295 Simple Statistics - Means	APP.C17
9.1-4A	WOS 295 Simple Statistics by MY	APP.C18-37
9.1-4B	WOS 295 Fleet A by MY - Means	78
9.1-4C	WOS 295 Arith. Means by MY Groups and Major Manufacturers	79
9.1-5	WOS 295 List by MY, MANUF, CID, MILEAGE	APP.C38-44
9.1-6	WOS 295 (75/84 MY) Simple Statistics - Means	APP.C45
9.1-7	WOS 295 (62/74 MY) Simple Statistics - Means	APP.C46
9.2-1A	OS 200 vs. Target List 200 (deviations)	APP.D1-5
9.2-1B	OS 200 List by MY, MANUF, CID, MILEAGE	APP.D6-10
9.2-2A	OS 200 Characteristics of Fleet B	80
9.2.-2B	OS 200 Sample Characteristics	APP.D11-12
9.2-2C	Characteristics of OS 200 vs. Target List 200	APP.D13
9.2-3	OS 200 Simple Statistics - Means	APP.D14
9.2-4A	OS 200 Simple Statistics by MY	APP.D15-19

Table	Title	Page
9.2-4B	OS 200 Fleet B by MY - Means	81
9.3-1A	Fleet C, LIST by TEST CAR - Part A	APP.E1-2
9.3-1B	Fleet C, LIST by TEST CAR - Part B	APP.E3-4
9.3-1C	Fleet C, Brief Characteristics	82
9.3-2A	Fleet C, Simple Statistics - Means	APP.E5
9.3-2B	Fleet C, by MY - Means	83
9.3-3	Fleet C, List by MY, MANUF, CID, MILEAGE	APP.E6-7
9.3-4	Fleet C, Matrix of Correlation Coefficients	APP.E8-9
9.4-1	Fleet D, (and retests of Fleet A)	85
9.4-2	Propane - vs. Gasoline-powered Cars (Fords, 140 CID)	APP.E11
9.4-3	Comparison of Propane to Gasoline Cars-Means	84
9.4-4	Retests of 5 private cars (from Fleet A)	86
9.4-5	Retests, Changes in Emissions, % rel.	87
10.1-1	Simple Correlation Coefficients, Fleet A (WOS 295), 1962-84 MY (295 cars)	90
10.1-2	Ditto, 1975-84 MY (248 cars)	91
10.1-3	Ditto, 1962-74 MY (47 cars)	92
10.1-4	Simple Corelation Coefficients between FTP-75 Results (EPWEIG) and MFTP-75 Phases (TBHOT:TBSTAB), Fleet A (WOS 295) and Fleet B (OS 200)	93
10.1-5	R-SQUARE of Multiple Linear Regressions, Fleet A (WOS 295) by MY Groups	94
10.1-6	R-SQUARE of Multiple Linear Regressions, Fleet A (WOS 295) by MY	96
10.1-7	Estimates of Model Parameters for Multiple Linear Regressions, Fleet A (WOS 295) by MY (1975-84)	97
10.1-8A	Ditto, by MY Groups	98
10.1-8B	Verification of Multiple Linear Model	99

Table	Title	Page
10.1-9	Ontario Criteria (Maximum Idle Emissions, according to Reg. 311, RRO 1980)	100
10.1-10	Compliance with ONTARIO Criteria, Fleet A (WOS 295), 1962-84 MY (295 cars)	102
10.1-11	Ditto, 1975-84 MY (248 cars)	103
10.1-12	Canada Standards and Equivalent Compliance Levels (CVS-2, in g/mile)	104
10.1-13	Compliance with CANADA Standards, Fleet A (WOS 295), 1962-84 MY (295 cars)	105
10.1-14	Ditto, 1975-84 MY (248 cars)	106
10.1-15	Mean Emission Levels - U.S. vs. Canada - specification Cars Fleet A (WOS 295), by MY	109
10.1-16	Mean Emissions and Standards - U.S. vs. Canada - specification Cars, Fleet A (WOS 295), by MY Group	110
10.1-17	Cross-compliance of ONTARIO with CANADA standards	111
10.1-18	WOS 295 Contingency Table, by MY Group	112
10.2-1	Criteria for Identification of Excessive Emitters	113
10.2-2	Excessive Emiters, Fleet A (WOS 295)	115
10.2-3	Excessive Emitters, List by MY	APP.F1
10.2-4A	Excessive Emitters, List by TEST CAR - Part A	APP.F2
10.2-4B	Excessive Emitters, List by TEST CAR - Part B	APP.F3
10.2-5	Excessive Emitters, Simple Statistics - Means	APP.F4
10.2-6	Non-Excessive Emitters, Simple Statistics-Means	APP.F5
10.2-7	WOS 295 Arith. Means with and without EE	116
10.2-8	Relative Frequency of Excessive Emitters in Ontario	116
10.2-9	WOS 295 Impact of Excessive Emitters on Means	117
10.3-1	OS 200 Simple Correlation Coefficients	119
10.3-2	OS 200 Compliance with CANADA, by MY Groups	120

Table	Title	Page
10.3-3	OS 200 Fail Rates by MY	121
10.3-4	OS 200 Arith. Means with and without EE	122
10.3-5	OS 200 Impact of Excessive Emitters on Means	122
10.3-6	Ontario and U.S. Emission Rates	124
10.3-7	Ratios of Ontario to U.S. Emission Rates (after elimination of EE)	125
10.4-1	Fleet C, Estimates of Model Parameters for Multiple Linear Regressions	126
10.5-1	Retests of Cars - Simple Statistics	128

LIST OF FIGURES

Figure	Title	Page/App.
6.1-1	Plan of Testing Facility	pg.49
6.1-2	View of the Test Bay	pg.49
6.1-3	View of the Instrumentation Room	pg.50
6.1-4	Gas Storage Room	pg.50
6.3-1,-2	Constant Volume Sampler - CVS	pg.53
6.3-3	Instrumentation Room	pg.53
6.4-1	Analytical Console	pg.53
	Invitational Letters A, B	B1-2
	Vehicle Inspection Sheet	B3
	Inspection/Receipt	B4
	Agreement	B5-6
	Test Vehicle Questionnaire	B7-8
	Release Form	B9

LIST OF FIGURES (Cont'd)

Figure		Title	Page/App.
9.1-1A,-1B	WOS 295	Plot of HC (FTP) vs. MY	C47-48
9.1-2A,-2B	WOS 295	Plot of CO (FTP) vs. MY	C49-50
9.1-3	WOS 295	Plot of NO (FTP) vs. MY	C51
9.1-4	WOS 295	Plot of FC (FTP) vs. MY	C52
9.1-5	WOS 295	Plot of CO-Idle vs. MY	C53
9.1-6	WOS 295	Plot of CO-Fast Idle vs. MY	C54
9.1-7A,-7B	WOS 295	Plot of HC (FTP) vs. CO (FTP)	C55-56
9.1-8A,-8B	WOS 295	Plot of HC (FTP) vs. CO-Idle	C57-58
9.1-9	WOS 295	Plot of CO (FTP) vs. CO-Idle	C59
9.1-10	WOS 295	Plot of CO-Fast Idle vs. CO-Idle	C60
9.1-11	WOS 295	Plot of HC (FTP) vs. CO-Fast Idle	C61
9.1-12	WOS 295	Plot of CO (FTP) vs. CO-Fast Idle	C62
9.1-13	WOS 295	Plot of FC (FTP) vs. CID	C63
9.1-14A,-14B	WOS 295 (75/84 MY)	Plot of HC (FTP) vs CO (FTP)	C64-65
9.1-15	WOS 295 (75/84 MY)	Plot of HC (FTP) vs. CO-Idle	C66
9.1-16	WOS 295 (75/84 MY)	Plot of CO (FTP) vs. CO-Idle	C67
9.1-17	WOS 295 (75/84 MY)	Plot of CO-Fast Idle vs. CO-Idle	C68
9.1-18	WOS 295 (75/84 MY)	Plot of CO (FTP) vs. CO-Fast Idle	C69
9.1-19	WOS 295 (75/84 MY)	Plot of FC (FTP) vs. CID	C70
9.1-20A,-20B	WOS 295 (62/74 MY)	Plot of HC (FTP) vs. CO (FTP)	C71-72
9.1-21	WOS 295 (62/74 MY)	Plot of HC (FTP) vs. CO-Idle	C73
9.1-22	WOS 295 (62/74 MY)	Plot of CO (FTP) vs. CO-Idle	C74
9.1-23	WOS 295 (62/74 MY)	Plot of CO-Fast Idle vs. CO-Idle	C75
9.1-24	WOS 295 (62/74 MY)	Plot of CO (FTP) vs. CO-Fast Idle	C76
9.1-25	WOS 295 (62/74 MY)	Plot of FC (FTP) vs. CID	C77

LIST OF FIGURES (Cont'd)

Figure		Title	Page/App.
9.2-1	OS 200	Plot of HC (FTP) vs. MY	D20
9.2-2	OS 200	Plot of CO (FTP) vs MY	D21
9.2-3	OS 200	Plot of NO (FTP) vs. MY	D22
9.2-4	OS 200	Plot of FC (FTP) vs. MY	D23
9.2-5	OS 200	Plot of CO-Idle vs. MY	D24
9.2-6	OS 200	Plot of CO-Fast Idle vs. MY	D25
9.2-7	OS 200	Plot of HC (FTP) vs. CO (FTP)	D26
9.2-8	OS 200	Plot of HC (FTP) vs. CO-Idle	D27
9.2-9	OS 200	Plot of CO (FTP) vs. CO-Idle	D28
9.2-10	OS 200	Plot of CO-Fast Idle vs. CO-Idle	D29
9.2-11	OS 200	Plot of CO (FTP) vs. CO-Fast Idle	D30
9.2-12	OS 200	Plot of FC (FTP) vs. CID	D31
9.3-1	Fleet C	Plot of HC (FTP) vs. CO (FTP)	E10
10.1-1,-2	WOS 295	Overlap of CANADA Compliance Groups	pg.107
10.2-1	Exc. Emitters	Plot of HC (FTP) vs. MY	F6
10.2-2	Exc. Emitters	Plot of CO (FTP) vs. MY	F7
10.2-3	Exc. Emitters	Plot of NO (FTP) vs. MY	F8

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ABBREVIATIONS, SYMBOLS AND CONVERSIONS

The following abbreviations and symbols are used in the report or in the referenced literature:

A2, A3	Automatic transmission with 2 or 3 gears
A/F	Air-fuel ratio (by weight)
Accel.	Acceleration
AGE	Age of vehicle (usually equal to: Test Year TY minus Model Year MY)
AIR	Air Injection (exhaust emission control system)
AM, AMC	American Motors Corp.
AN	Automotive News (US Magazine)
ARB	Air Resources Branch (of MOE)
BAG	Plastic bag (of Tedlar Mylar, Teflon) for sampling of diluted gases
bbl, BBl	Barrels (in carburetor)
BHP-hr	Brake horsepower-hour
C	Compact-size (car)
C, °C	Degrees Centigrade (Celsius)
C, CAN	Canada
CAN-car	Canada-specification car (other than US-specification car)
CAT	Catalytic muffler (or simply: catalyst)
cc, CC	Cubic centimeter (= 0.061 cu. inch)
CFO	Critical Flow Orifice (device for calibration of CVS equipment)
cfm, CFM	Cubic feet per minute (flow)
CH	Chrysler Corp.
CID	Cubic inch displacement (of engine); CID = litres x 61.02
CL	Chemiluminescence analyzer (for NO, NO_x)
CNG	Compressed natural gas (fuel, based mainly on methane)
CO	Carbon Monoxide (pollutant)
CO_2	Carbon Dioxide (product of complete combustion)

COLD	Cold-start portion (first 505 seconds) of CVS-2, also known as BAG 1.
Cold-start	Testing after vehicle kept for over 12 hours at 68 to 86°F.
CTC	Castlefield Test Centre (operated by MOE)
CVS	Constant Volume Sampler
CVS-1	Mass-emission test procedure using CVS (also known as FTP-72)
CVS-2	Mass-emission test procedure using CVS (also known as FTP-75)
CY	Calendar Year
Cyl, CYL	Cylinders
D	Diesel-powered (vehicle)
Decel.	Deceleration
DEF	Defective, missing or inoperative (emission control)
DTC	Downsview Test Centre (operated by MTC)
DYN	MTC Dynamometer Procedure; e.g., DYN-1; DYN-9 (= MFTP)
EGR	Exhaust Gas Recirculation (system to control NO_x emissions)
ENV	Environment (Canada or Ontario)
EPA, EP	Environmental Protection Agency (US)
EP Act	Ontario Environmental Protection Act
EVAP	Evaportive Emission Control System
F	Full-size (car)
F, °F	Degrees Fahrenheit
FC	Fuel Consumption (in litres per hundred kilometers); FC = 282.47/FE
FE	Fuel Economy (in miles per gallon imp.); FE = 282.47/FC
FI	Fuel Injection system
FI-	Fast Idle (mode, usually 2500 RPM)
FID	Flame-ionisation detector (analyzer for HC)
FO, F	Ford Motor Comp.
FR	Federal Register (US)
FTP-68	Federal (US) Test Procedure applicable starting with 1968 MY
FTP-72	Federal (US) Test Procedure applicable starting with 1972 MY (also known as CVS-1)

FTP-75	Federal (US) Test Procedure applicable starting with 1975 MY (also known as CVS-2)
FY	Fiscal Year (usually April 1 to March 31 next)
G	Gasoline-powered (vehicle)
g,	Grams
gal	Gallons (imp.); gal = 4.546 litres = 1.2 gallons U.S.
GC	Gas Chromatograph
GM, GMC	General Motors Corp.
gpm, g/mi	grams per mile (mass-emissions)
GVW	gross vehicle weight
H_2	Hydrogen
H_2O	Water
HC	Hydrocarbons (pollutants)
HD-	Heavy-duty (vehicle)
HFET	Highway Fuel Economy Test (EPA test procedure)
Hg	Mercury
HI	High
HOT	Hot-start portion (505 seconds) of CVS-2, also known as BAG 3.
hot-start	Testing after engine warm-up to normal operating temperature
hp, HP	Horse power
I-, ID-	Idle (mode)
I/M	Inspection/Maintenance Program
IR	Infra-red (type of analyzer for CO, CO_2, HC), also known as NDIR, i.e., non-dispersive IR.
JAPCA	Journal of the Air Pollution Control Association (US magazine)
kg, KG	Kilogram (= 1000 grams = 2.205 pounds)
km, KM	Kilometer (= 0.61 miles)

l, L	Litre (= 1000 cc = 0.220 gallons imp.)
L4, L6	Line-engine with 4 or 6 cylinders
lbs	Pounds (mass); 1 lb = 453.6 grams
LD-	Light-duty (vehicle)
LFE	Laminar-flow element (device for calibration of CVS equipment)
LO	Low
m	Meter (=1.094 yards)
M	Medium-size (car)
M3,M4,M5	Manual transmission with 3, 4, or 5 gears
Max	Maximum
MD-	Medium-duty (vehicle)
MFTP-68	Modified FTP-68 (hot-start)
MFTP-75	Modified FTP-75 (hot-start) also known as TB (two-bag test) or DYN-9
MGS	Ontario Ministry of Government Services
Min	Minimum
MMT	Methylcyclopentadienyl manganese tricarbonyl (fuel additive)
MOD	Engine Modification (exhaust emission control system)
MOE	Ontario Ministry of the Environment
MOEn	Ontario Ministry of Energy
mpg, MPG	Miles per gallon imp. (also called gasoline or fuel mileage)
mph, MPH	Miles per hour (speed)
MTC	Ontario Ministry of Transportation and Communications
MY	Model Year (of a vehicle)
n, N	Number of observations
N_2	Nitrogen
NBS	National Bureau of Standards, (U.S. agency)
NE	Non-excessive emitter (in HC and/or CO, FTP)
No	Number (of items or serial number)
NO	Nitric Oxide (pollutant)
NO_2	Nitrogen Dioxide (pollutant)
NO_x	Oxides of Nitrogen (usually as NO_2)

O_2	Oxygen
O_3	Ozone
ONT	Ontario (Province)
OPP	Ontario Provincial Police
OS 200	Ontario Sample of 200 cars (representing mid-1982 population)
P	Propane-powered (vehicle)
PAH	Polycyclic Aromatic Hydrocarbons
PAN	Peroxyacetyl Nitrate (component of smog)
Part,PART	Particulates (e.g. soot, dust)
Pb	Lead
PCV	Positive Crankcase Ventilation
PNA	Polynuclear Aromatics
ppb,PPB	Parts per billion (10^{-9}, concentration)
ppm,PPM	Parts per million (10^{-6}, concentration)
ppmv,PPMV	Parts per million (by volume)
psi,psig	Pounds per square inch gauge (pressure)
r, R	Correlation coefficient
R-SQUARE	Coeff. of determination, R^2
rpm,RPM	Revolutions per minute (of engine)
RRO	Revised Regulation of Ontario (specifically Reg. 311, RRO 1980)
RY	Registration Year
S	Subcompact-size (car)
SAE	Society of Automotive Engineers
S.D., SD	Standard Deviation of Mean
sec	Seconds
SO_2	Sulfur Dioxide (pollutant)
SS	Stainless Steel
STAB	Stabilized portion (867 seconds) of CVS-2, also known as BAG 2.

TB	Two-bag test (also MFTP-75) is a modified hot-start test procedure based on CVS-2
TEL	Tetraethyl lead (fuel additive)
THC	Total hydrocarbons
Tr, TR	Transmission Type (A2, A3, M3 - M5)
TT	Test Type
TY	Test Year
U,US,U.S.	United States
US-car	US-specification car (controlled to meet EPA standards)
USAGE	Usage of car (usually: current Calendar Year CY minus Model Year MY)
UV	Ultra-violet (type of analyzer for NO)
V	Venturi (= barrels of carburetor)
V6, V8	V-engine with 6 or 8 cylinders
VEU,VES	Vehicle Emissions Unit (Section) of ARB
VIN	Vehicle Identification Number
VOC	Volatile Organic Compounds (mostly hydrocarbons, aldehydes)
vol.	Volume
vs.	Versus (against, in contrast to)
WOS 295	Wider Ontario Sample of 295 cars
%v.	Per cent (by volume)
%, %rel.	Per cent (relative)
%w.	Per cent (by weight)

1.0 EXECUTIVE SUMMARY

1. In Ontario, gasoline-powered vehicles contribute about 39% of HC, 72% of CO and 30% of NO_x, with LD-vehicles being the strongest source (1978).

2. In 1969, Ontario became the first province in Canada to institute emission control programs: a certification at the new car manufacturers' level and a spot-checking program for in-use cars. Between 1969 and 1982, over 100,000 cars were tested using generally the Ontario Idles Test.

3. While U.S. standards have become more and more stringent, Canadian standards have been frozen for thirteen years (1975-87). This brought about the introduction of Canada-specification cars (meeting only the more lenient Canadian standards) and resulted in a need to measure their true mass-emissions and fuel economy.

4. Between 1977-79 MOE joined MTC in a cooperative effort to build a mass-emission test facility at Downsview (DTC). MOE's share in responsibilities and test time was approximately 40%. A program to assess exhaust emission (HC, CO, NO_x) and fuel consumption (FC) from typical Ontario in-use cars was started in 1979, and 374 cars were tested by June 1984. All cars were tested in "as received" condition (including fuel), using Ontario Idles Test, FTP-75 procedure and a shorter, hot-start MFTP-75 procedure.

5. Two samples of Ontario cars were collected and evaluated: a sample of 200 (OS 200), which represents a sales-weighted Ontario car population as of mid-1982, and a wider sample of 295 (WOS 295), which included additional vehicles, mostly of newer MY.

6. Results indicate:
- general trend to higher HC, CO, NO_x and FC with older models;
- very good correlation between HC and CO;
- no correlations between NO_x and HC, and between NO_x and CO.

7. Almost half (48%) of OS 200 failed one or more of the four Ontario Idles criteria (under Reg. 311, RRO 1980).

8. Almost three-quarters (74%) failed one or more of the three Canada standards (or equivalents) for HC, CO and NO_x. One car in six failed all three standards.

9. The Idles Test is very useful in predicting compliance with Canada HC and CO standards (74% of WOS 295 were in agreement; i.e., correctly passed or correctly failed), but is not relevant to the NO_x standard. (Note: Two fail codes, CANADA and ONTARIO, were developed as tools for judging compliance).

10. Samples show that 7-9% of cars are excessive emitters (EE) in HC and/or CO. Due to bias in sampling, the actual EE frequency is estimated at over 15%. EE cars are on the average 6x higher in HC and 4x higher in CO than the non-excessive cars. An estimated 15% of EE cars contribute about 51% of HC and 41% of CO.

11. Excessive emitters are identifiable by the Idles Test. Their control alone would reduce HC emissions by 27% and CO by 16%.

12. US-specification cars (built to meet stricter U.S. standards) are not achieving their full low-emission potential.

13. The shorter test (MFTP) correlates very well with FTP-75 and will be useful in increasing surveillance capacity and in accumulating a data base for emission factors.

14. Ontario emission rates for 81-84 MY are substantially higher than U.S rates (by 70-155% in HC, by 35-75% in CO and by 145-200% in NO_x).

15. Two propane cars, while low in HC and CO, are 5x higher in NO_x than comparable gasoline cars.

16. It is recommended to continue the surveillance program, to investigate deactivation of catalysts, and emissions of propane and CNG vehicles. Expansion and upgrading of DTC should be considered mainly to enable research into particulates and their carcinogenic components.

2.0 INTRODUCTION

2.1 Background and Chronology

(a) Motor Vehicles are a Major Source of Pollution in Ontario

The significant contribution of motor vehicle exhaust gases to air pollution in Ontario was recognized in 1957, when one of the findings of a report by the Select Committee of the House stated "that the internal combustion engine is one major source of air pollution which must be controlled" (L1).

While only sparse quantitative data were available at that time, emission inventories conducted at a much later date (e.g., by Environment Canada and by MOE in 1980) confirmed that legislative and control actions undertaken by Ontario in 1967 (Air Pollution Control Act) and in 1971 (Environmental Protection Act) were fully justified.

In Table 2.1 - 1 contributions by all transportation sources are shown for individual pollutants (L2,3,4). Environment Canada survey for 1978 estimates that Ontario gasoline-powered vehicles contribute about 39% of HC, 72% of CO and 30% of NO_x. The LD gasoline-powered vehicles are the most numerous and, as a group, the strongest single source of HC, CO and NO_x in Ontario.

(b) Ontario Introduces Controls but Lacks Mass-Emission Data

In 1969, as the first province in Canada, Ontario initiated certification of new motor vehicles and assessment of in-use vehicles (L5,6,7).

In January 1971, when the certification of new motor vehicles became a federal responsibility (L8,9), Ontario continued with assessment of in-use vehicles using the modified FTP-68 procedure and subsequently the Idles Test. Neither of these procedures was capable of producing mass-emission data (for details see Sections 2.2 and 2.3).

Table 2.1 - 1

Contribution of Transportation Sources to Total Emissions in Ontario

Survey No.	Area (Source)	Ref. Year	Pollutant (as % rel. of all sources) HC	CO	NO_x	Part.	SO_2	Notes
1	Ontario (Transportation)	1976	62.0	87.6	59.4	7.6	.9	(1) (2)
2A	Ontario (Transportation)	1978	45.8	81.5	61.2	7.5	2.7	(1) (3)
2B	Ontario (gasoline-powered)	1978	38.6	72.3	30.4	4.1	.4	(1)(3)(5)
3	Ontario (Transportation)	1980	72.7	96.2	63.4	19.9	.9	(4)
4	Toronto (Transportation)	1980	66.4	98.1	47.4	22.4	1.3	(4)

Notes: (1) Contributions by Forest Fires which vary greatly from year to year were excluded from total.

(2) Environment Canada, 1976 Inventory of Emissions (L2).

(3) Environment Canada, 1978 Inventory of Emissions (L3).

(4) Environment Ontario, 1980 Emission Summaries for Ontario and Toronto (L4).

(5) Includes gasoline-powered motor vehicles only.

(c) Relation of Canada to U.S. Emission Standards

Canada emission standards introduced in 1971 were, until the end of 1974, identical to U.S. emission standards. From 1975, while the Canadian standards remained the same (i.e. at the 1975 level), the U.S. standards became progressively more stringent, see Table 2.1-2.

Table 2.1 - 2

Ratios of Canada/U.S. Exhaust Emission Standards for LD - Vehicles (by Model Year) (4)

Model Year MY	HC	CO	NO_x	Note
1971-74	1.0	1.0	1.0	(1)
1975-76	1.3	1.7	1.0	(2)
1977-79	1.3	1.7	1.6	(2)
1980	4.9	3.6	1.6	(2)
1981-87	4.9	7.4	3.1	(2)
1988-	1.0	1.0	1.0	(3)(1)

Notes:
(1) Canada standards in lock-step with U.S.
(2) Canada standards "frozen" for thirteen years (1975-1987), while U.S. standards became progressively more stringent.
(3) By 1988 Canada standards for HC, CO and NO_x should be tightened up to the U.S. levels.
(4) Canada and U.S. standards in g/mile are shown in Table 2.2 - 1.

(d) Introduction of Canada-Specification Cars

To save on emission control costs, to improve fuel economy and in some cases to enable the use of cheaper leaded fuel, some car manufacturers in 1975 MY introduced separate Canada-specification cars (ie. cars meeting only the more lenient Canadian standards). The fraction of these cars in Ontario has risen from approximately 45% in 1975/76 to approximately 80% in 1980/83 (L10).

While emission characteristics of US-specification in-use vehicles have been thoroughly studied by the EPA since 1968 (see Section 2.3), mass-emission data of Canada-specification in-use cars are not known (see Section 2.4).

(e) Impact of Ontario Climatic Conditions

It seems likely that the Ontario climatic and road conditions (lower winter temperatures - snow - greater use of salt - corrosion) negatively affect the effectiveness and durability of the control system components, thus resulting in higher exhaust emissions.

(f) Since 1975, U.S. Emission Factors not Applicable

It is quite obvious that U.S. emission factors are no longer applicable to Ontario emission inventories and that their use would result in greatly underestimating all three regulated pollutants (i.e. HC, CO and NO_x).

Also, the absence of realistic emission factors for NO_x has made it difficult to estimate the contribution of Ontario LD vehicles to air quality, oxidants and acidic deposition problems.

(g) Discovery of Excessive Emitters in Ontario

Data from the Ontario spot-checking program (conducted from 1969 to 1982 using MFTP-68 and/or Idles Test) indicate the presence of a significant number of in-use vehicles with greatly excessive emission levels. Mass-emission data of these excessive emitters and their contribution to average emission rates of typical Ontario cars are not known.

(h) Other Concerns and Requirements for Data

As well as the above problems, there are concerns about:

- lack of fuel consumption (FC) data characterizing the Ontario car population, which are deemed a necessary ingredient of emission inventories;
- lack of insight into emission characteristics of different Canadian exhaust control systems (CAT, AIR, MOD, FI);
- lack of access to a testing facility that could be used to investigate and assess mass-emissions from alternate fuel vehicles (propane, CNG, alcohol).

In 1975 and 1976 the above problems and concerns were unsolved and unanswered. There was a lack of a positive policy towards automotive emission programs and of funds (some $500,000) to build and staff a MOE mass-emission testing facility. In 1976, the situation changed.

(i) Start of MTC-MOE Cooperation

In October 1976, the Vehicle Emissions Section (VES) was informed by MTC's Automotive Vehicle Energy Management Group, that a chassis dynamometer would likely be purchased and installed at the MTC - Downsview property. It would be used for research work on vehicle fuel economy sponsored by the Ministry of Energy (MOEn). At the same time inquiries were made regarding recommendations for test procedures and exhaust analyzers (for tune-up purposes) (L11). This was perceived by MOE as a unique opportunity to provide the Ontario government with a complete mass-emission testing facility. A suggestion was made to order a dyno fully compatible with the FTP-75 test procedure in which case ARB (VES) would be interested in contributing the following items to a joint MTC/MOE test facility: Constant Volume Sampling system (CVS), analytical console, calibration gases and equipment, services of one analyst, maintenance of equipment and technical back-up.

(j) Construction of MTC/MOE Testing Facility

Between February 1977 and July 1979 the testing facility was designed and constructed by the cooperative effort of MTC, MOEn, MGS and MOE. It is housed in a modified shop of a building at 1201 Wilson Avenue, Downsview, Ontario (L12). First trial tests were run in August 1979.

The tentative agreement about test time usage (after taking into consideration the needs and contributions of MTC and MOE) gave MTC approximately 60% (Mondays - Wednesdays) and MOE approximately 40% (Thursdays and Fridays) of test time.

(k) MOE Funding and Testing Activities

The MOE share of this joint project was initially funded by diverting approximately $35,000 to $50,000 per fiscal year from the VES regular budget.

From the start of testing in 1979, to end of August 1984, over 400 cars supplied by MOE have been tested using the cold-start mass-emission procedure (FTP-75). Most of these cars are representative of the typical Ontario car population as of mid-1982. Review and discussion of these test results is the subject of this report.

2.2 U.S., Canada and Ontario Emission Standards

In the U.S., emission standards for new LD-vehicles were introduced nationwide with the 1968 MY (based on Clean Air Act, 1967). All 1967 and older LD-vehicles (i.e., cars, station wagons, vans and pick-up trucks with GVW of 6000 lbs or less) are therefore considered uncontrolled. This is to some degree a simplification, due to the fact that Positive Crankcase Ventilation (PCV) systems to control engine blow-by have been installed nationwide on new cars since the 1963 MY. Also, new cars of the 1966 and 1967 MY sold in California had already been controlled for HC and CO to the same level as introduced nationwide with the 1968 MY.

Exhaust emission standards are only meaningful when considered in context with the test procedure, including the type of analyzers used. In the "old days", i.e., in California in 1966-67 and in U.S. in 1968, undiluted (concentrated) exhaust emissions from the tailpipe were measured on a concentration basis (as ppmv or %v). Infra-red analyzers were used to measure HC (usually two IR analyzers were employed, one for low range of concentrations, one for high range) and to measure CO and CO_2. Vehicle was driven on a chassis dynamometer over a prescribed driving cycle (7-mode, 7-cycle cold-start test), which was usually referred to as FTP-68 (i.e. Federal Test Procedure applicable starting with the 1968 MY). No attempt was made to measure the total volume of exhaust gases and to establish mass-emissions. Instead, three sets of standards were used, depending on engine size, as a means of crude compensation for differences in total volumes of exhaust gases generated by engines of different sizes.

CID Group	HC (ppmv)	CO (%v.)
50-100	410	2.3
101-140	350	2.0
141-999	275	1.5

These were also the standards that Ontario introduced for the certification of 1969 MY cars (L6).

Further developments of Ontario, U.S. and Canada standards and test procedures are shown in Table 2.2 - 1 and described in attached Notes.

Table 2.2 - 1

LD-Vehicle Exhaust Emission Standards in U.S., Canada and Ontario - in grams per mile

(Equivalent levels in terms of CVS-2 are shown in brackets)

		U.S.			Ontario (1969-70) Canada (1971-88)			
MODEL YEAR	TEST PROCEDURE	HC	CO	NO_x	HC	CO	NO_x	NOTE
Pre-1968 Uncontrolled	(CVS - 2)	(8.7)	(87)	(4.65)	(8.7)	(87)	(4.65)	= BASE
1968	7 - mode	(3.2)	(23)	-	No standards in			(1)
	(CVS - 2)	(6.0)	(34)	(4.0)	Canada or Ontario			(4)
1969	7 - mode	(3.2)	(23)	-	(3.2)	(23)	-	(2)
	(CVS - 2)	(6.0)	(34)	(4.0)	No standards in Canada			(4)
1970	7 - mode	2.2	23	-	2.2	23	-	(3)
	(CVS - 2)	(4.1)	(34)	(4.0)	(4.1)	(34)	(4.0)	(4)
1971	7 - mode	2.2	23	-	2.2	23	-	(5)
	(CVS - 2)	(4.1)	(34)	(4.0)	(4.1)	(34)	(4.0)	(4)
1972	CVS - 1	3.4	39	-	3.4	39	-	(6)
	(CVS - 2)	(3.0)	(28)	(4.0)	(3.0)	(28)	(4.0)	(4)
1973-74	CVS - 1	3.4	39	3.0	3.4	39	3.0	(7)
	(CVS - 2)	(3.0)	(28)	(3.1)	(3.0)	(28)	(3.1)	(4)
1975-76	CVS - 2	1.5	15	3.1	2.0	25	3.1	(8)
1977-79	CVS - 2	1.5	15	2.0	2.0	25	3.1	(9)
1980	CVS - 2	.41	7.0	2.0	2.0	25	3.1	(10)
1981-87	CVS - 2	.41	3.4	1.0	2.0	25	3.1	(11)
(waiver)			(7.0)					(11)
1988-	CVS - 2	.41	3.4	1.0	.41	3.4	1.0	(12)

Notes:

BASE:Estimated mass-emission levels of uncontrolled (pre-1968) LD vehicles in U.S. and Canada (Ontario), based on CVS-2 (Constant Volume Sampling procedure using cold-start FTP-75, introduced with 1975 MY).

(1) Standards were first introduced in U.S. Shown are estimated mass-emission levels based on cold-start 7-mode, 7-cycle test procedure, called FTP68. All analyzers are infrared, NDIR (L13a). No standards in Canada or Ontario.

(2) Standards (identical to U.S.) were introduced in Ontario (L6). No federal standards in Canada.

(3) HC standards made more stringent in U.S. and Ontario. All analyzers are infrared, NDIR (L13b). No federal standards in Canada.

(4) Estimated equivalent levels, based on CVS-2 mass-emission test procedure.

(5) Standards for HC and CO (identical to U.S.) were introduced in Canada under Canada Motor Vehicle Safety Act, 1970. No separate standards in Ontario from now on.

(6) More stringent standards legislated in U.S. and Canada, based on new mass-emission procedure CVS-1 (i.e. FTP-72). A Flame Ionization Detector (FID) was introduced for analysis of HC (L14).

(7) Standard for NO_x was introduced in U.S. and Canada, based on CVS-1 and using chemiluminescence analyzer CL (L15).

(8) HC and CO standards were tightened up substantially in U.S. and slightly in Canada. To meet these standards, many car manufacturers introduced the oxidation catalysts. Also, CVS-2 became the official certification test procedure. Canadian standards were to be kept unchanged for eleven years (i.e., from 1975-1985 MY).

(9) NO_x standard made more stringent in U.S., no change in Canada.

(10) HC and CO standards made more stringent in U.S., no change in Canada.

(11) CO and NO_x standards made more stringent in U.S., with a possible waiver to 7.0 g/mi CO. No change in Canada.

(12) No waivers allowed in U.S. More stringent Canadian standards were introduced in 1987 and made applicable to 1988 MY. So after 13 years of "independence", the Canadian standards are again identical to U.S.

2.3 EPA Emission Factor Testing Programs

Since 1968, the U.S. Environmental Protection Agency (EPA) has been conducting Emission Factor Programs with the objective to characterize, quantify and reduce the air pollution caused by mobile sources, including automobiles, motorcycles, trucks and buses. Each year approximately 400 to 2200 in-use vehicles have been tested in 2 to 7 cities. Over the years a large data base on in-use vehicles has been accumulated and used at various levels of government to make decisions and predictions. These data have been used in air pollution inventories, Environmental Impact Statements, to evaluate impact of Inspection/Maintenance programs (I/M) and to assess compliance of vehicles with U.S. federal emission standards.

EPA testing programs for individual fiscal years are briefly surveyed in Table 2.3 - 1. Originally (in 1968-70 FY) the testing was conducted by EPA staff in two cities (Kansas City and Houston). Since FY 1971, it has been conducted under contracts with independent laboratories and expanded to six or seven cities: usually Phoenix, Denver, Chicago, Houston, Washington D.C., St. Louis and Los Angeles. (Some testing has been also performed in San Antonio, Newark and Detroit).

Table 2.3 - 1

EPA Emission Factor Testing Programs for Light-Duty Vehicles (cars and light-trucks)

Fiscal Year (FY)	Total Vehicles Tested	Model Year	Number of Cities Sampled	Note
71	N/A	1957 1971	6	
72	N/A	1966 1972	6	
73	1080	1967 1974	6	
74	1973	1965 1975	7	
75	2236	1966-1976	7	incl. some diesels
76	None	(Due to program overlaps, no program in 1976 FY)		
77	2027	1972-1978	6	incl. 20 diesels
78	1495	Trucks Only	N/A	
79	2040	N/A	6	
80 & 81	1639	Mostly 1980-1982	7	
82 & 83	674	N/A	N/A	

Results for 1971-79 FY have been published as reports (L16-19) and statistically evaluated (as supporting data for EPA models Mobile 1 and Mobile 2). Starting with 1980 FY, EPA has been accepting test results from the contractors in computer readable form only (i.e. in the form of a computer tape or disk) and no separate reports in paper form have been published. Statistical evaluation of results is being continued (in the form of attachments to Mobile 2), but these data contain information on US-specification (i.e. highly controlled) cars only. No EPA data are available on Canada-specification cars (L20).

Also, EPA made considerable efforts to try out shorter types of certification tests and to establish their correlations with the official federal certification test procedure CVS-2 (L51,52).

2.4 Environment Canada Emission Test Programs

Under the Canada Motor Vehicle Safety Act, 1970, automobile manufacturers are required to certify that new motor vehicles offered for sale in Canada (starting with the 1971 MY) conform to current emission standards.

Each model year, Environment Canada (under contract from Transport Canada) conducts CVS-2 tests at the Ottawa Test Centre on 40 to 50 new motor vehicles (representing the most popular makes, models and engine families) to verify that their emissions meet Canadian standards. All of these vehicles are tested at the 4,000 miles point. Several of these cars (possibly four to six each year) are tested repeatedly while accumulating up to 50,000 miles (L21). Emission test results from this surveillance program have been kept by Environment Canada and have not been released for public use.

Over the years several additional testing projects have been conducted or supported by Environment Canada:

(a) Mass-emission testing of vehicles at low ambient temperatures (between -10°F to +60°F, instead of the normal baseline temperature range of 68°F to 86°F). Small fleets of vehicles were tested (up to 12 cars in a fleet).

(b) Mass-emission testing of vehicles powered by new power sources (such as a turbine diesel engine) and by alternate fuels (such as propane, hydrogen and alcohol mixtures). Eight vehicles were involved in one such project.

(c) Short testing (in idles) of approximately 1000 in-use vehicles in Alberta (in 1978-79 FY).

(d) Short testing (in idles) of 518 cars in Nova Scotia, approximately 250 cars in Rimouski, Quebec and 520 cars in Charlottetown, PEI. The objective of these projects (conducted usually in cooperation with provincial authorities) was to verify suggested idle emission guidelines for in-use vehicles. Surveillance programs conducted by Enviroment Canada are shown in Table 2.4-1 (as reported in Annual Reports 1975-1981).

Table 2.4 - 1

Environment Canada Test Programs

Fiscal Year	Approx. Number of Vehicles Tested Using CVS-2	Model Years Involved	Mileage Group	Note
1975-76	50	75 & 76	low-mileage	
1976-77	40	76 & 77	"	
1977-78	50	77 & 78	"	
1978-79	50	78 & 79	"	
1979-80	N/A	N/A	N/A	
1980-81	48	80 & 81	low-mileage	

The above information indicates that Environment Canada mass-emission test programs focus mainly on low-mileage cars (at 4000 miles) and are conducted for certification, surveillance and internal purposes only.

2.5 Ontario Emission Test Programs

In Ontario, exhaust emission certification of new motor vehicles started one year after the U.S., i.e., with the 1969 models (L6). Ontario certificates were automatically issued to new car manufacturers and importers, based on copies of certificates issued by the US Environmental Protection Agency (EPA). In 1969-71 Ontario exhaust emission standards and test procedures were identical to the US standards and procedures (see Table 2.2-1, above).

2.5.1 Ontario Spot-checking Program

As a logical extension of the certification program, a surveillance inspection and test program was instituted in Ontario by the fall of 1969. It was based on random sampling of in-use vehicles in the Toronto area, where cars from on-going traffic were randomly selected, stopped by a policeman and directed to the MOE test site.

This spot-checking program was later expanded to cover up to 14 municipalities in Ontario each year. Also, the test procedure underwent several changes as shown in Table 2.5 - 1 and as explained below.

Phase I (1969-1971 TY) testing was done mainly using the modified FTP-68 procedure (i.e., hot-start 2-cycle 7-mode test). Components of the emission control system were inspected under the hood. Exhaust emission tests were performed using two mobile vans, each equipped with an analytical console using IR analyzers for HC, CO and CO_2, a portable dynamometer (road-simulator with limited loading capacity) and each manned by a crew of three test staff (with occasional help by 1-2 summer students).

In 1970, after some experimenting with several shorter types of tests (e.g., Idle Neutral, Idle Drive, steady 30 mph, Fast Idle at 2000-2500 RPM, Ontario short cycle, California 77-second test), an Idles Test was instituted (Nov. 1970), first as the only test performed (following the under-the-hood visual inspection). In Phase I a total of 8949 tests were performed, of which 95% were long tests (MFTP-68), and 5% were short tests (Idles).

In Phase II (1972-1973 TY) testing continued along the same lines with emphasis shifting from Long Test (MFTP-68) to Idles Test. This change in testing procedures was a combined result of three major policy decisions made by different governments:

(a) In Canada, under the Motor Vehicle Safety Act, the certification of new motor vehicles became a federal responsibility (as of January 1, 1971), while in-use vehicles remained the responsibility of each province.

(b) In the US, the EPA announced and instituted (with the 1972 MY) a completely new mass-emission test procedure FTP-72, which made the FTP-68 obsolete. (Note: While the earlier procedure was essentially a volumetric test, the new procedure was a true mass emission test. It required the use of a chassis-dynamometer and a Constant Volume Sampler and was therefore also known as CVS-1 procedure. The cost of this new test equipment was estimated in 1971 at approximately $200,000 per unit).

(c) In Ontario, MOE made decisions:

- to continue assessment of in-use vehicles by using the (now obsolete) MFTP-68;
- to gradually increase usage of the short (Idles) test while phasing out the MFTP-68; and
- to not implement the newest FTP-72 (CVS-1) procedure, mainly due to the high investment cost.

In Phase II, 13,196 tests were performed, of which over 75% were short (Idles) test.

In Phase III (1974-1977 TY) the Idles Test was used almost exclusively and between 10,000-13,000 cars were tested each year. The long test (MFTP-68) has been used for special projects only. By 1977 the long test was phased out completely; it was very difficult and costly to maintain the portable road-simulators and the analytical equipment, and the test procedure had been obsolete for a number of years.

In Phase IV (1978-1982 TY) the spot-checking program using Idles Test has been continued, but at a gradually reduced rate, mainly due to diversification of control activities (introduction of a program involving used-car dealership inspections, checking of muffler shops, visits to colleges to educate future mechanics, etc.). By end of 1982 it was discontinued due to lack of staff.

In total, during Phases III and IV over 78,000 cars were tested using almost exclusively (99.6%) the Idles Test. Compliance with Ontario emission standards (for Idle HC, Idle CO, Fast Idle HC, Fast Idle CO; introduced by Regulation 561 in 1979, now 311 RRO, 1980) has been approximately 50% (i.e., approximately 50% of cars failed to meet one or more of the four criteria).

In Phase V (1983-1984 TY) the spot-checking program has been discontinued. Only 2273 cars were tested in 1983 TY, all in Idles. These cars were not sampled at random, but were either volunteered or sent to the Castlefield Test Centre by Metro Police after being issued a Form 1 (i.e. Notice to submit motor vehicle to an inspection. These are issued under Reg. 311, RRO 1980 in cases of visible emissions or suspected emission control tampering). Note: Castlefield Test Centre activities will be reviewed in a separate report.

Table 2.5 - 1

Ontario Spot-checking Programs by Test Year and Test Type

Test Year	Total Cars Tested	Modified FTP-68	Idles Test Only	Idles Test (as % of all tests	Test Phase	Notes
1969	56	54	2	3.6	I	
1970	3,734	3,553	181	4.8		(1)
1971	5,159	4,850	309	6.0		
1972	6,659	2,038	4,621	69.4	II	
1973	6,537	1,213	5,324	81.4		
1974	12,978	147	12,831	98.9	III	(2)
1975	12,430	32	12,398	99.7		
1976	10,544	137	10,407	98.7		
1977	11,224	5	11,219	99.9		
1978	8,333	-	8,333	100.0	IV	
1979	7,319	-	7,319	100.0		
1980	5,815	-	5,815	100.0		
1981	4,642	-	4,642	100.0		
1982	4,770	-	4,770	100.0		(3)
1983	2,273	-	2,273	100.0	V	(4)
1984	(730)	-	(730)	100.0		(4)(5)

Notes: (1) Since November 1970 an Idles Test (i.e. HC & CO in Idle and Fast Idle) has been included as part of the modified FTP-68 test.

(2) Use of MFTP-68 test was practically discontinued in July 1974.

(3) Random spot-checking program was discontinued by end of 1982.

(4) Biased sampling (mainly volunteers and "Form 1" cars).

(5) 1984 TY includes the first eight months only.

2.5.2 Ontario Mass-emission Program (MOE)

Independently of the Ontario spot-checking program (1969-1982 TY) described above, a mass-emission surveillance program was conceived in 1977 and instituted in 1980. (This test program is the subject of this report.)

Number of cars tested each year (by owner group) are shown in Table 2.5-2. Usually just over 80 cars can be tested in a year (not including retests) and a total of 390 cars have been tested to date (i.e. until end of August 1984).

Table 2.5 - 2

Ontario Mass-emission Surveillance Program by Test Year and Car Owner

Test Year TY (1)	Cars Tested in TY (1)(2)	Total Cars since 1979	Private & Company	Rental	Dealers	Ontario Gov't	Note
1979	14	14	-	-	-	14	
1980	80	94	14	3	6	57	
1981	84	178	80	4	-	-	
1982	82	260	68	14	-	-	
1983	80	340	51	14	14	1	
1984	50	390	39	11	-	-	(1)
1979-84	390	390	252	46	20	72	(1)(2)

Notes: (1) 1984 TY includes the first eight months only.

(2) Not including retests.

3.0 TEST PROGRAM OBJECTIVES AND DESIGN

One of the prerequisites of an emission test program is the availability of a suitable testing facility. To build, equip, staff and maintain the emission analysis part of the MTC/MOE joint testing facility at Downsview Test Centre (DTC) became one of the objectives of the Vehicle Emissions Section (VES) for the 1977/78 and 1978/79 fiscal years (FY). It was during these two years, that the foundations for the current emission test program were laid (see more in Chapter 6).

In the 1979/80 FY, an emission test program was established by VES, and later given the title: "Exhaust Emission Surveillance of Ontario In- Use Cars".

3.1 Test Program Objectives

(a) To assess exhaust emissions (of HC, CO, NO_x) from typical Ontario in-use cars, based on a sample of 200 cars representing the Ontario car population as of mid-1982.

(b) To establish the base level for Ontario automotive emissions control strategies and criteria for their evaluation.

(c) To establish a data base for generating more representative emission factors for Ontario emission inventories and air quality modelling (acid rain, oxidants).

(d) To estimate compliance of Ontario's cars with Canadian emission standards.

(e) To assess average emissions from excessive emitters and estimate the impact of their increased occurrence (due to tampering, fuel switching) on the population mean.

(f) To establish a correlation between cold-start (FTP-75) and hot-start (MFTP-75) test procedures thus providing a supplementary, faster and cheaper testing method.

(g) To establish average fuel consumption data needed as a basis for Ontario emission inventories.

3.2 Test Program Design

The overall purpose of the test program is to test a representative sample of Ontario in-use cars. Our studies of previously conducted US surveillance programs and practical considerations led to the establishment of the following outlines and limitations:

(a) Sample to consist of 200 cars (based on consideration of testing capacity available to VES, i.e., 80-90 cars per year. Sample size is discussed in more detail in Section 4.2).

(b) Reference point for establishing representative car population to be mid-1982, i.e., July 1, 1982.

(c) Sample to closely represent existing Ontario car population (as of mid-1982) in terms of composition by manufacturers, model years, car sizes, engine sizes and accumulated mileage. These parameters to be specified in the Target List 200.

(d) Recruitment of vehicles for testing (based on target list) to be done in greater Metro Toronto area (where the test facilities are located).

(e) Majority (approximately 90%) of vehicles in sample to be privately or company owned. Cars from other owner groups (rental companies, used car dealers, gov't. vehicles) to be used as emergency substitutions only, up to a maximum of 10%.

(f) Cars to be tested in as-received condition, i.e., without any prior adjustments or tune-ups, and using the original fuel and tires (as supplied with the vehicle).

(g) Testing to consist of: inspection of emission control system, short test (HC and CO in idles), a mass-emission cold-start test (FTP-75) and a mass-emission hot-start test (MFTP-75). Both mass-emission tests to be conducted on a dynamometer using the CVS-2 test procedure.

(h) Fuel consumption to be calculated from the CVS-2 emission results using the carbon-balance method.

(i) Excluded from testing will be vehicles having:

- diesel engines (these require a larger CVS system for exhaust sampling)
- faulty brakes on driven wheels (for safety reasons)
- leaky exhaust systems (unknown part of exhaust stream by-passes the CVS)
- serious smoke problems (fine particulates contaminate the bags, analyzers and cause HC hang-ups)
- worn-out or damaged tires (for safety reasons)

Also excluded will be vehicles submitted by highly fuel economy oriented owners, or by automotive mechanics.

(j) A questionnaire showing among other items the usage and maintenance of the test vehicle will be filled out by each private car owner.

(k) Compensation to car owners to consist of a cash payment only, depending on the size and age of vehicle. (Initially $40 to $80; from July 1982: $50 to $90 per car).

(l) Special insurance policy to be arranged, covering damage to vehicles and other liabilities, while test cars are being handled by MOE or MTC staff.

4.0 TEST VEHICLE SELECTION

Ontario motor vehicle registrations (as compiled by MTC, L22) show in the 1978 registration year approximately 4.7 million active motor vehicles:

1.	Passenger vehicles	3,597,371
2.	Trucks & Tractors (commercial)	738,836
3.	Buses (inc. school buses)	19,814
4.	Farm vehicles	32,182
5.	Motorcycles	86,377
6.	Mopeds	9,511
7.	Snow vehicles	199,502
	TOTAL (1978)	4,683,593

From the second category (trucks & tractors), 433,443 vehicles are pick-up trucks and vans with gross vehicle weight (GVW) under 2401 kg (5293 lbs), i.e. actually LD-vehicles of similar GVW as cars. This brings the total number of LD-vehicles to be sampled to just over 4.0 million.

This chapter discusses the composition and characteristics of the Ontario car population (Section 4.1), establishes size of representative sample (Section 4.2), describes procedures and criteria used to specify the sample of 200 cars (Section 4.3) and lists all 200 target cars (Section 4.4).

4.1 Vehicle Population Data

Data characterizing the Ontario vehicle population, and specifically LD-vehicles, have been compiled from different sources.

Table 4.1-1 shows Ontario Motor Vehicle Registrations by registration year (usually December 1 to November 30) as compiled yearly by MTC (L22). It should be noted, that from 60% to 75% of vehicles in the commercial category are vehicles with GVW under 6000 lbs i.e., LD-vehicles. (Note: Newest MTC figures for the 1983 passenger category indicate that not all vehicles tabled in that category in 1982 and previous years should be considered fit and active).

Table 4.1-2 splits Passenger Car Registrations into groups by cylinders (which roughly indicates split by engine sizes).

Between 1964 and 1978 the share of 4-cyl. cars grew from 13% to 20%, while 6-cyl. declined from approximately 50% to 21%, and the 8-cyl. increased from 37% to 59%. To represent mid-1982 car population it was estimated, that 4-cyl. category would further increase by 9% (to 29%) at the cost of 8-cyl. category (59% to 50%) and that 6-cyl. category would remain unchanged (at 21%). These percentage shares (29/21/50) were then aimed for while composing the Target List 200.

Table 4.1-3 shows New Vehicle Registrations and Sales, by calendar year and vehicle category. In 1978 approximately 377,500 new passenger vehicles and 104,200 new trucks were registered in Ontario. These figures (in conjunction with U.S. scrappage rates) were helpful in verifying representation of model years in Target List 200.

Table 4.1-4 reviews (in columns a to i) data characterizing U.S. and Ontario car populations by model year (MY). U.S. data for 1968-1978 years, shown in columns a to f, seem to be fairly consistent. Ontario data were available for 1966 (from an authoritative source, R.L. Polk & Co, but obsolete), for 1973 (from ENV Canada, based on drivers survey in Toronto) and for 1975 (by MOE, based on partial survey of cars spot-checked mainly in 1975). This 1975 survey (column i) shows 2/3 of all cars in the age group 0-3, and was disregarded due to suspected bias in sampling. Another partial survey of MOE spot-checking data was then produced in 1980 (col. j) which does not indicate any significant bias (due to more representative sampling instituted in 1975-76). This partial 1980 survey was then used as a basis for compilation of both Target Lists (see col. k and l).

Additional information was extracted from U.S. car registration data for 1962-73. Simple (1-year) and compounded average survival factors were calculated, see Table 4.1 - 5, and later used for verification of age distribution of cars in Ontario sample. These data indicate e.g. that in the U.S. about 36% of cars survive for more than ten years, and about 10% for more than fourteen years.

Table 4.1 - 1

Ontario Motor Vehicle Registration (in 000's) (1)

Registration Year	Passenger & Dual Purpose (STW)	Commercial (Trucks, Tractors, Buses, Farm Vehicles) (3)	Motorcycles	TOTAL	Notes
1910	4.2	-	-	4.2	
1920	155.9	16.2	5.5	177.6	
1930	496.9	61.7	3.9	562.5	
1940	612.4	86.1	5.4	703.9	
1950	887.6	202.8	13.7	1,104.1	
1960	1,732.9	320.2	9.4	2,062.5	
1970	2,576.0	426.3	45.3	3,047.6	
1975	3,224.6	614.6	72.5	3,911.7	
1976	3,341.9	669.8	78.3	4,090.0	
1977	3,490.5	767.1	82.9	4,340.5	
1978	3,597.4	790.8	86.4	4,474.6	
1979	3,692.0	856.0	90.0	4,638.9	
1980	3,751.9	1,173.3	96.9	5,022.1	(2)
1981	3,831.0	1,112.4	107.2	5,050.6	(2)
1982	3,842.7	1,091.4	119.6	5,053.7	(2)
(1983)	(3,420.0)	(800.0)	(135.0)	(4,355.0)	(4)
1984	3,904.7	882.0	146.2	4,932.9	(5)

Notes: (1) 1910-1982 figures are from MTC 1982 statistics (L23).

(2) No explanation given by MTC for sudden increase in commercial vehicles in 1980 to 1982 registration years.

(3) Commercial category contains large number of vehicles under 6000 lbs GVW, i.e., LD-vehicles (estimated from 60% to 75% of commercial vehicles shown).

(4) Preliminary unchecked data by MTC, showing fit and active vehicles only. To be used as rough estimates only (L24).

(5) MTC statistics (L25).

Table 4.1 - 2

Ontario Passenger Car Registrations by Cylinders (% of relative frequency) (1)

Registration Year	Relative Frequency by Group (in % rel.) 4-cyl	6-cyl	8-cyl & more	TOTAL (% rel.)
1964	13.1	49.7	37.2	100.0
65	13.0	48.4	38.6	"
66	12.6	46.7	40.7	"
67	12.4	44.0	43.6	"
68	12.3	40.5	47.2	"
69	12.2	36.7	51.1	"
1970	12.8	33.7	53.5	"
71	14.2	30.6	55.2	"
72	15.6	27.8	56.6	"
73	17.4	24.3	58.3	"
74	17.9	23.2	58.9	"
75	18.4	22.2	59.4	"
76	19.0	21.1	59.9	"
77	19.2	20.7	60.1	"
78	19.9	20.9	59.2	"
79	20.3	21.3	58.4	"
1980	21.9	22.3	55.8	"
81	24.0	22.6	53.4	"
82	26.4	23.2	50.4	100.0

Notes: (1) MTC statistics - 1982, pp. 1-6, (L23).

Table 4.1 - 3

New Vehicle Registrations and Sales in Ontario (in 000's) by Calendar Year and Vehicle Category

	Passenger Vehicle		Trucks	
Calendar Year	Registrations (R.L. Polk) (1)(2)	Sales (MVM Assoc.) (3)	Registrations (R.L. Polk) (1)(2)	Sales (MVM Assoc.) (3)
1960		191.2		25.3
61		181.0		23.4
62		203.5		26.4
63		229.7		31.1
64		251.3		35.6
65	292.4	297.5	38.1	39.2
66	277.8	283.7	41.3	42.8
67	268.5	274.3	42.6	45.0
68	303.3	307.0	48.1	50.7
69	315.2	319.1	52.0	53.2
70	260.9	265.0	42.3	44.9
71	321.8	325.8	50.2	53.4
72	335.3	346.8	65.5	68.2
73	374.2	387.3	76.2	81.9
74	332.2	359.4	85.4	93.7
75	345.3	409.1	86.5	100.3
76	347.4		93.1	
77	382.7		103.4	
78	377.5		104.2	
79	380.8		105.1	
80	322.0		86.7	
81	334.9		78.4	
82	281.0		55.9	

Notes: (1) Figures for 1965-1966 are by R.L. Polk & Company (L26).

(2) Figures for 1967-1982 are by R.L. Polk & Company (L23).

(3) See sources L26, L27.

Table 4.1 - 4

Data on Average Age Distribution in U.S. and Ontario Car Populations (in % rel., usually at mid-year, i.e. end of June)

	U.S. Car Populations						Ontario Car Populations										
Age	Pre-1969	1972	1973	1976	1968-70, 1972-76	1978	1966	1973 (Toronto only)	Partial 1975 TY	Partial 1980 TY	Target List 100	Target List 200	1980 TY	1981 TY	1982 TY	End 1983 RY	Roll-back to mid-1982 RY
Col.	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
-1	-	-	-	-	-	-		-	1.6	-	-	-	-	-	-	2.6	-
0	9	8.3	8.9	6.6	7.5	7.2	9.7	12.5	16.9	9.2	9.0	9.0	9.6	7.5	6.0	7.9	5.0
1	12	10.3	11.3	7.9	10.7	10.1	14.5	13.1	19.3	12.4	12.0	12.5	12.8	12.4	11.1	7.0	9.3
2	11	10.2	9.7	10.0	10.7	9.2	12.4	10.8	17.5	11.8	12.0	12.0	12.6	13.1	10.8	9.2	9.6
3	10	10.6	9.6	11.4	10.6	7.1	10.2	9.4	12.7	11.1	11.0	11.0	12.2	11.8	11.4	9.4	10.0
4	9	9.9	9.9	10.1	10.0	9.2	9.0	10.0	9.0	10.4	10.0	10.5	11.3	10.9	10.8	9.7	10.8
5	9	8.7	9.2	8.4	9.2	10.3	7.8	8.3	7.4	9.6	10.0	9.5	8.9	10.7	10.6	0.2	10.3
6	7	9.2	7.9	8.2	8.5	8.9	8.0	5.6	6.0	7.8	8.0	8.0	9.1	8.2	8.8	9.5	10.0
7	7	8.8	8.2	7.9	7.7	7.1	7.2	3.1	3.9	7.4	7.0	7.0	7.9	7.1	7.2	9.0	7.8
8	6	6.8	7.5	7.0	6.6	6.6	5.0	3.1		5.5	6.0	5.5	6.0	6.1	7.1	6.6	
9	5	5.5	5.5	5.5	5.2	5.9	4.8			4.0	4.0	3.5	3.3	4.8	5.5		
10	4	3.9	4.1	5.0	3.9	4.8	3.9			2.5	3.0	3.0	2.8	2.6	3.5		
11	3	2.1	2.8	4.0	2.7	3.5			5.7	2.1	2.0	2.0	1.6	1.7	2.2		27.2
12	3		1.4	2.6	1.8	3.0		23.9		1.5	2.0	1.5	.9	1.3	1.6	18.9	
13	1	5.7	1.1	1.8	1.4	2.3	7.5			.9	1.0	1.0	.6	.8	1.3		
14	1		.6	1.1	.9	1.5				.7	1.0	1.0	.2	.4	1.1		
14+	3		2.3	2.5	2.5	2.4				3.1	2.0	3.0	.2	.6	1.0		
Total %	100	100.0	100.0	100.0	99.9	100.1	100.0	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total Cars in Survey							2.0 $\times 10^6$	640	9513		100	200	5814	4128	4233	3.4 $\times 10^6$	3.4 $\times 10^6$

Notes:

(1) AGE = Test Year minus Model Year

(2) Sources of data (by columns):

(a) Journal of the APCA, 19, No. 12 of December 1969, pg. 920.

(b,c) 1973/74 Automobile Facts and Figures, MVM Association, Detroit, Mich. 1974.

(d) Automotive News Data Book, 1978 Edition

(e) Mobile 1, Attach 2, pg. 3 "Methodology for Applying Attach. 1 Credits" U.S. EPA; March 1978.

(f) "National Mobile 2 Variable Estimates", pg. 3, U.S. EPA, November 1980.

(g) MVM Association, Facts and Figures of the Automotive Industry, Table 33, Toronto, 1967 Edition.

(h) ENV Canada, Canadian Automobile Driver Survey, Report EPS 3-AP-73-10, Table 21, October 1973.

(i) Ontario Ministry of the Environment, ARB, Vehicle Emissions Section, Partial survey SF 26/A of cars tested in Ontario between April 1975 and January 1976.

(j) MOE, ARB, VES: Partial survey of cars tested in Ontario during approximately seven months of 1980 Test Year.

(k) MOE, Initial composition of Ontario Target List 100 (mid-1980), based on (j).

(l) MOE, Final composition of Ontario Target List 200 (mid-1982), based on (j).

(m-o) MOE: Final surveys of cars tested in Ontario in 1980-1982 Test Years.

(p) Ontario Ministry of Transportation and Communications (MTC), Licensing and Control Branch, Preliminary data on vehicle population by model year, as of end December 1983 (Passenger cars, fit and active).

(q) MOE: Roll-back of MTC data shown in (p), to mid-1982 registration year. (Estimated by VES).

Table 4.1 - 5

Simple (1-year) and Compounded Survival Factors for Cars (U.S. data for 1962-1973 calendar years) (2)

Usage Group (1)	Simple (1-year) Factors			Compounded Factors
	Range from	to	Avg.	Avg.
0-1	1.000	1.000	1.000	1.000
1-2	.978	.999	.995	.995
2-3	.973	.999	.990	.985
3-4	.970	.993	.985	.970
4-5	.960	.986	.975	.946
5-6	.945	.975	.960	.908
6-7	.916	.951	.925	.840
7-8	.837	.911	.885	.744
8-9	.775	.859	.830	.617
10-11	.690	.780	.745	.359
11-12	.673	.771	.720	.259
12-13	.681	.769	.715	.185
13-14	.681	.756	.715	.132
14-15	.701	.772	.715	.095

Notes: (1) Usage = Calendar Year minus Model Year

(2) MVM Association: Facts and Figures (U.S.), 1974 edition (L27).

4.2 Size of Representative Sample

With over 4.0 million LD-vehicles in Ontario and an expected yearly testing capacity of some 85 cars, it was quite obvious from the beginning that the sample could only be a very small fraction of the population.

Two procedures, statistical and comparative, were employed to arrive at the estimated sample size, the results were then scrutinized and a final sample size established using common sense and compromise.

4.2.1 Statistical Procedures

Emission levels of HC, CO, CO_2, NO_X and the fuel consumption FC (based mainly on CO_2) are all quantitative and continuous variables. The task is usually to estimate population mean μ and population standard deviation σ based upon sample mean X and sample standard deviation S. Determination of required sample size n is done after specifying maximum allowable error E (in estimating μ) and the desired degree of confidence γ (so that the resulting sample mean X does not differ from μ by more than ± E). Usually it is best to start calculations after assuming or estimating the population standard deviation σ .

In the first approximation to n, several different approaches and formulas (L28-31) were tried, assuming S = 0.33 (same for all components), N = 8, E = 5% and γ = 95%. Resulting n ranged between 156 to 209 cars.

Unfortunately, in the case of car exhaust emissions each of the four components - HC, CO, NO_X, FC - yields a different S and the sample size calculations then result in four different n. (Theoretically, the largest n should be used as the final sample size).

In the second approximation, to calculate n we used double sampling and employed two formulas recommended by the EPA.

The first equation is recommended for evaluation of retrofit devices (L32) and the sample size is given by:

$$\underline{n} = \frac{4.S_1^2}{w^2}\left(1 + \frac{2}{N}\right).g_\alpha^2 \qquad \text{(F1)}$$

where:

$\underline{n}$ size of total sample

S_1^2 variance of first sample (expressed as fraction)

w full width of desired confidence interval (expressed a fraction)

N size of first sample

g_α the normal deviate exceeded with probability α

In our case N = 12 and w = 0.1 (for error ± 5%) and g = 1.96 (for γ = 95% confidence and α = 0.05). The above formula is then reduced to:

$$\underline{n} = \frac{4(1 + 2/12)\ (1.96)^2 \times S_1^2}{(0.10)^2} = 1792.75 \times S_1^2$$

Table 4.2 - 1 (in lines F1) shows the estimated sample sizes for 95% and 90% confidence levels.

The second equation, derived from EPA formula for quality assurance (L31), is simpler:

$$\underline{n} = \left(\frac{2S \times g}{w}\right)^2 \qquad \text{(F2)}$$

where values of g (taken from statistical tables for t-distribution) are 1.960 (for 95% conf. level and $\underline{n}$ over 120) or 1.645 (for 90% conf. level). Again the estimated sample sizes are shown in Table 4.2 - 1, lines F2.

The second approximation (using EPA formulas F1 & F2) yielded generally much higher sample sizes, from 91 to 606 (at 95% conf.), mainly due to higher S values. Lowering the confidence level from 95% to 90% reduces the estimated sample sizes in a ratio $(1.96)^2$ to $(1.645)^2$; i.e. by approximately 30%, to a range from 64 to 427 cars.

4.2.2 Comparative Procedures

Sample sizes used in similar U.S. programs were investigated:

(a) An EPA program evaluating efficiency of various exhaust emission retrofit devices (L32) sets a sample size of 113 vehicles as a maximum (based on allowable error of ± 5% and 90% confidence level). The objective of testing is merely to find mean reductions in emissions (in % relative) by testing before and after the installation of a retrofit device, and not to establish absolute levels of emissions (e.g. in g/mile).

Table 4.2 - 1

Calculation of Sample Size n (based on data from testing 12 cars)

Based on Formula	Variable		Conf. Level %	HC	CO	NO_X	FC	Note
	Mean	in g/mi	95	2.233	36.810	2.740	12.920	(1)
	S (Stand. Dev.)	in g/mi		1.027	21.400	1.177	3.140	(1)
	S	as fraction		.460	.581	.429	.243	(1)
	S^2	as fraction		.212	.338	.184	.059	(1)
F1	n (for 95% conf.)		95	380	606	330	106	(2)
F1	n (for 90% conf.)		90	268	427	232	75	(2)
F2	n (for 95% conf.)		95	326	519	283	91	(3)
F2	n (for 90% conf.)		90	230	366	199	64	(3)

Notes: (1) Survey of 12 cars tested by MOE, SAS Job #16.
(2) see source L32.
(3) see source L31.

(b) In 1975, 1977 and 1979 Fiscal Years (FY), EPA conducted surveillance programs (L16,17,19) in seven cities: Chicago, St. Louis, Phoenix, Houston, Washingston, in high-altitude City of Denver, and in Los Angeles (representing California's much more stringent standards). Sample sizes for each city and FY are shown in Table 4.2 - 2. It is worth noting that in the two cities, where significant deviations from the U.S. (49-states) emission standards were expected (i.e. in Denver and L.A.), the sample size of 200 cars was considered a minimum.

TABLE 4.2 - 2

Sample Sizes Used by EPA during 1975, 1977 and 1979 FY Surveillance Programs

City (Sampling Site)	1975 FY (1)	1977 FY FY (2)	1979 (3)	Note
Chicago	517	432	-	
St. Louis	506	389	325	
Phoenix	499	385	325	
Houston	133	250	54	
Washington D.C.	133	250	325	
Denver (high-altitude city)	200	321	325	
Los Angeles (California)	200	-	200	(4)
Total (in Fiscal Year)	2188	2027	2042	

Notes:
(1) see source L16.
(2) see source L17.
(3) see source L19.
(4) California standards are since 1972 more stringent than U.S. (49-states) standards.

4.2.3 Final Sample Size for Ontario

From statistical procedures (Sect. 4.2.1) it follows, that a sample of 200 to 430 cars would be necessary to establish mean X with a 90% confidence level and with a maximum error of ± 5%. If one were to focus mainly on HC and NO_x (the two most important pollutants contributing to volatile organic compounds and acid rain problems), and were to accept lower confidence levels and/or higher error when establishing CO, the necessary sample size range would be reduced to 200 to 270 cars.

Due to the fact that Canada-specification cars constitute a separate population, which differs from US-specification (49 states) cars about as much as California cars do, it seemed logical to use the same minimum for Ontario sample size as the EPA used in Los Angeles sampling in 75 and 79 FY (see Table 4.2-2), i.e., 200 cars.

In the next step, a more realistic view of the testing capacity was taken. Although it was planned to perform some 90 tests per year, not all tests could have been expected to be complete and useful. It was estimate that some 10-15 tests would be lost due to equipment failures (car, dyno, analytical console, computer) and that another 10-15 tests would be done on off-target cars (mainly due to unavailability of target vehicles and last moment substitutions). These assumptions meant that only 60-70 cars could be written off the Target List each year and that it would take approximately three years to finish testing a sample of 200 cars and approximately four years to finish a sample of 270.

Based on the above considerations, and after rejecting a four-year test program, the final size of the Ontario sample was set at 200 cars. This was a large enough sample to establish HC and NO_x with 90% confidence (and ± 5% error) and was deemed achievable in three years.

4.3 Sample Selection Procedures and Criteria

The objective was to provide data, procedures and criteria for specifying model years, makes, car sizes (and possibly models), engine sizes and mileage ranges for all 200 cars in a balanced sample representing Ontario car population as of mid-1982, in other words for compiling what was to be called Target List 200. (This was necessary due to unavailability of recent or detailed information on the true composition of the car population in Ontario).

(a) First, data on yearly new car registrations in Ontario (as compiled by R.L. Polk & Co.) were extracted for 1968 to 1981 Registration Years (L33). Usually some 95 different makes/ models are listed (see sample in Table 4.3-1, Attach. A1).

(b) These data are showing a large number of models for the three major manufacturers: up to 20 for CH, up to 1 for FO and up to 26 for GM. To simplify these data, four basic car size groups were established based on GVW ranges, see Table 4.3-2.

Table 4.3 - 2

Car Sizes by GVW

Size Group	Size Symbol	GVW Range (lbs)
Subcompact	S	under 2500
Compact	C	2500 - 3000
Mid-size	M	3000 - 3500
Full-size	F	3500 - 6000

Note: Sorting of cars into these groups was based on GV only and in some cases was different from the manufacturer's size designation used for marketing purposes.

(c) Individual models made by AM, CH, FO, GM were then rated by GVW and assigned into one of the four size groups within each manufacturer (e.g., in 1977 MY Pinto, Bobcat, Capri and Fiesta went into group S, Fairmont, Mustang and Zephyr into C, Granada and Monarch into M and the rest into group F). Frequencies of cars (in the size group, by manufacturer and registration year are then shown in Table 4.3 - 3.

(d) Data from MOE spot-checking program (conducted mainly at the Castlefield Test Centre) were evaluated to establish the popularity (frequency) of engine families; e.g. in the 1979 MY the most popular Ford engine was 302 CID: on 49 cars, then 351 CID: on 38 cars, then 14 CID: on 28 cars, 200 CID on 16 cars, etc. Engine popularities were evaluated for 1968-1981 MY and all manufacturers (L34).

(e) Data from the MOE spot-checking program (L35) were also evaluated for average mileage accumulation with age of cars, and preferred mileage ranges were established for each MY group of target cars. Range specified in Table 4.3 - 4, were meant to provide guidance to the project technician (while selecting potential test cars using the Target List 200), with the objective of limiting the selection of cars with unusually high or low mileages (e.g. a 1981 car, with 80,000 km). Note: Discretion was used, especially when dealing with cars over 5-6 years old due to possibility of odometer roll-overs and rollbacks.

(f) In the next step, data on age distribution in Ontario (based on partial survey of 1980 TY, see Table 4.1 - 4, col. j) were combined with Ontario new car registrations (in Table 4.3 - 3) to obtain basic specifications for the Target List 200, see Table 4.3 - 5.

This Table shows the number of cars to be tested, apportioned by manufacturers, car size groups and model years; e.g. Ford is represented by 40 cars, of which number six are subcompacts (i.e. under 2500 lbs GVW), nine are compacts, six are mid-size and nineteen full-size. Imports are represented by five manufacturers only: Toyota, Datsun, VW, Honda and Mazda (due to good showings of these makes in recent years, and also to provide some insight into intrinsic relation between emission performances of older and newer models of these five makes).

Table 4.3-3

Ontario New Car Registration (between 1968-1981)

		Cars (in 000's) registered in Calendar Year CY														
MANUF	Weight Class	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67/60
AM	Subc.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Comp.	5.3	6.3	7.5	1.7	2.7	3.7	5.3	12.9	10.1	5.5	4.9	3.9	.9	-	
	Mid-s.	1.3	1.4	1.0	6.8	5.3	6.9	8.8	.7	.9	1.0	-	.9	5.9	5.3	
	Full-s.	-	-	-	.4	1.1	1.4	2.1	3.1	3.1	3.2	3.1	3.5	2.2	4.8	
	AM	6.6	7.7	8.6	8.9	9.1	12.0	16.2	16.7	14.1	9.7	8.0	8.3	9.0	10.1	
	AM-%	2.0	2.4	2.3	2.4	2.4	3.5	4.7	5.0	3.8	2.9	2.5	3.2	2.9	3.3	3.0
CH	Subc.	32.2	15.0	17.3	13.5	4.4	1.5	-	-	3.0	2.6	2.2	-	-	-	
	Comp.	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Mid-s.	10.5	24.1	29.6	33.6	36.0	33.6	26.6	36.8	41.5	34.4	30.4	27.0	26.1	22.5	
	Full-s	2.1	3.8	14.4	19.6	35.1	35.8	39.6	26.4	23.7	23.4	22.3	21.1	28.2	33.3	
	CH	45.8	42.9	61.5	66.6	75.8	70.8	66.1	63.2	68.2	60.5	54.9	48.1	54.3	55.8	
	CH-%	13.7	13.3	16.2	17.6	19.8	20.4	19.1	19.0	18.2	18.0	17.1	18.4	17.2	18.4	18.0
FORD	Subc.	13.1	4.6	6.6	15.9	8.3	6.7	8.4	12.1	11.2	10.1	7.8	3.0	-	-	
	Comp.	22.1	18.0	25.8	15.4	9.5	9.2	12.6	20.3	16.1	11.2	10.9	10.9	10.4	-	
	Mid-s.	2.7	15.5	8.9	12.4	16.5	12.1	9.3	3.1	7.7	24.4	19.1	18.5	24.5	33.0	
	Full-s	8.0	10.0	34.1	34.5	43.9	38.3	43.5	42.1	46.5	29.8	34.3	32.5	40.4	46.6	
	FORD	45.9	48.1	75.4	78.1	78.2	66.6	73.7	77.5	81.4	75.5	72.1	64.9	75.3	79.6	
	F-%	13.7	14.9	19.8	20.7	20.4	19.2	21.3	23.3	21.8	22.5	22.4	24.9	23.9	26.3	27.0
GM	Subc.	24.2	15.8	17.1	14.3	7.5	9.9	8.9	18.0	22.0	8.6	7.7	.4	-	-	
	Comp.	29.8	38.3	17.2	4.3	2.7	2.8	3.2	.5	-	-	8.5	-	-	-	
	Mid-s.	70.7	84.6	86.3	88.3	34.7	30.5	26.3	19.5	19.9	48.5	40.0	39.2	51.4	36.1	
	Full-s	28.1	24.1	65.6	60.4	113.9	100.9	99.9	88.3	102.5	58.2	58.6	43.0	77.6	80.7	
	GM	152.8	162.8	186.3	167.2	158.8	144.2	138.2	126.3	145.5	115.3	114.8	82.5	29.0	16.8	
	GM-%	45.6	50.6	48.9	44.3	41.5	41.5	40.0	38.0	38.9	34.4	35.7	31.6	40.9	38.5	39.0
IMPORTS	Datsun	9.7	7.0	5.0	7.0	8.2	7.0	7.8	8.4	13.9	15.9	15.0	9.3	4.7	1.2	
	Toyota	16.8	11.2	4.5	8.1	10.4	8.7	9.7	10.6	15.1	18.4	18.2	9.5	4.4	1.8	
	VW	7.6	7.8	10.4	10.7	10.2	8.6	6.3	7.3	10.3	12.0	13.5	15.4	16.2	16.4	
	Honda	20.7	15.3	10.9	16.5	17.5	11.5	6.3	1.8	-	-	-	-	-	-	
	Mazda	11.5	5.0	2.7	2.7	2.8	1.1	1.6	1.9	3.3	3.7	2.5	1.2	-	-	
	Volvo	2.9	2.7	2.5	2.1	2.1	2.1	3.0	4.2	4.3	4.2	4.2	3.4	2.8	3.0	
	BL/L*	5.0	3.9	5.8	2.7	4.2	4.2	4.6	3.8	4.6	4.0	4.5	5.2	5.6	5.3	
	Others	9.6	7.6	7.1	6.9	5.3	10.7	12.3	11.0	13.5	16.1	14.1	13.0	13.9	13.3	
	IMPORT	83.8	60.5	48.9	56.7	60.7	53.9	51.6	49.0	65.0	74.3	72.0	57.0	47.6	41.0	
	IM-%	25.0	18.8	12.8	15.0	15.9	15.5	14.9	14.7	17.4	22.2	22.4	21.9	15.1	13.5	13.0
ALL	(000's)	334.9	322.0	380.8	377.5	382.7	347.5	345.8	332.7	374.2	335.3	321.8	260.8	315.2	303.3	N/A
MANUF	%	100.0	100.0	100.0	100.0	100.0	100.1	100.0	100.0	100.1	100.0	100.1	100.0	100.0	100.0	100.0

Note: BL/L*: British Leyland (until 1978); LADA (from 1979-1981)

The total number of 1982 MY cars to be tested (18) is lower than the total of 1981 MY cars (25). This is due to the fact that the Target List 200 represents mid-1982 population (as of July 1, 1982), by which time only approximately 70% of 1982 MY cars would be sold.

(Note: As an interim measure, to enable sampling of Ontario cars in 1980, a provisional list of 100 cars representing the mid-1980 population, was compiled using the age distribution shown in Table 4.1 - 4, col. k. This used to be called the Target List 100. Later on it was incorporated into the final Target List 200, see List A in Table 4.4 - 1).

Table 4.3 - 4

Preferred Mileage Ranges of Target Cars (by MY and CID)

	50-140 CID				141-999 CID			
Model Year	Miles $x10^3$		Kilometers $x10^3$		Miles $x10^3$		Kilometers $x10^3$	
	from	to	from	to	from	to	from	to
1982	3	15	5	24	3	15	5	24
81	8	21	13	34	9	24	15	39
80	14	37	23	60	16	42	26	68
79	20	53	32	85	23	60	37	97
78	26	69	42	111	29	76	47	122
77	31	83	50	134	34	90	55	145
76	36	97	58	156	38	102	61	*
75	41	11	66	*	43	115	69	*
74	46	124	74	*	47	126	76	*
73	50	135	81	*	51	138	82	*
72	54	146	87	*	55	149	89	*
71	58	*	93	*	59	*	95	*
70	63	*	101	*	64	*	103	*
69	67	*	108	*	68	*	110	*
68	71	*	114	*	72	*	116	*
62-67	74	*	119	*	75	*	121	*

Note: *... over 160 (i.e. 160,000 miles or km, as applicable).

Table 4.3-5

Basic Specifications for Target List 200

		Cars in Sample (by model year - MY)																TOTAL	
MANUF	Weight Class	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67/60	All Cars	%
	Subc.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Comp.	-	1	1	-	-	-	-	-	1	-	-	-	-	-	-	-	3	1.5
AM	Mid-s.	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	3	1.5
	Full-s.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	AM	-	1	1	-	1	-	1	1	1	-	-	-	-	-	-	-	6	3.0
	Subc.	1	2	1	1	1	-	-	-	-	-	-	-	-	-	-	-	6	3.0
	Comp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CH	Mid-s.	1	1	2	2	2	2	1	1	1	1	1	-	-	-	-	-	15	7.5
	Full-s	-	-	-	1	1	2	2	2	1	1	-	1	-	-	-	1	12	6.0
	CH	2	3	3	4	4	4	3	3	2	2	1	1	-	-	-	1	33	16.5
	Subc.	1	1	1	1	1	-	1	-	-	1	-	-	-	-	-	-	7	3.5
	Comp.	2	2	1	1	1	-	1	-	1	-	-	-	-	-	-		9	4.5
FORD	Mid-s.	-	-	1	1	-	1	-	-	-	-	1	-	1	-	-	1	6	3.0
	Full-s	-	1	1	2	2	2	2	2	1	1	1	1	-	1	1	1	19	9.5
	FORD	3	4	4	4	4	4	3	3	2	1	2	1	1	1	1	2	40	20.0
	Subc.	1	1	1	1	1	-	1	-	-	1	-	-	-	-	-	-	7	3.5
	Comp.	2	3	3	1	-	-	-	-	-	-	-	-	-	-	-	-	9	4.5
GM	Mid-s.	4	5	6	5	5	2	1	1	1	-	1	-	-	-	-	1	32	16.0
	Full-s	2	3	2	4	3	6	5	4	3	2	1	1	1	1	1	1	40	20.0
	GM	9	12	12	11	9	8	7	5	4	3	2	1	1	1	1	2	88	44.0
	Datsun	1	1	1	1	-	1	1	1	-	1	-	-	-	-	-	-	8	4.0
	Toyota	1	1	1	-	1	1	-	1	1	-	1	1	-	-	-	-	9	4.5
	VW	-	1	1	1	1	-	-	-	1	-	-	-	1	-	-	1	7	3.5
IMPORTS	Honda	1	1	1	1	1	1	1	-	-	-	-		-	-	-	-	7	3.5
	Mazda	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1.0
	Volvo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	IMP.	4	5	4	3	3	3	2	2	2	1	1	1	1	-	-	1	33	16.5
ALL	All	18	25	24	22	21	19	16	4	11	7	6	4	3	2	2	6	200	100.0
MANUF	%	9.0	12.5	12.0	11.0	10.5	9.5	8.0	7.0	5.5	3.5	3.0	2.0	1.5	1.0	1.0	3.0	100	100.0

4.4 Target List 200

Data from Table 4.3-5, which is essentially the basic scenario for a list of cars to be tested, were combined with information on commonly used engines (from manufacturer's specifications and reference manuals, L36-42) and with data on popularity of different engines in Ontario (as acquired by MOE in 1969-1981, L34-35).

A Target List of 200 cars, representing Ontario car population as of mid-1982, has been compiled and is shown in Table 4.4-1 (Attach. A2-A8). It consists of List A (Target cars #1-100, which is actually the preliminary Target List 100 mentioned above) and List B (Target cars #101-200). It specifies: model year (MY), manufacturer (MAN) car size group (S,C,M,F), number of cylinders (4,6,8), engine displacement (CID, L), and provides optional information on number of venturis in the carburetor (VENT). In some cases alternative engines (Engine II) are shown, based on engine popularity.

In addition to this Target List 200, another parallel list was compiled for the convenience of the project technician, showing preferred mileage ranges (see Table 4.3-4 above) and suggested car models (e.g., as target car #146a, 1980 Fairmont, Zephyr or Mustang were suggested).

Omitted were specifications regarding type of transmission (A or M). These were originally part of preliminary Target List 100, but were found to be very restrictive and impractical. (Some U.S. studies conducted by contractors for the EPA specify transmission type, but allow only 70% match, L17). No attempt was made to specify a particular type of emission control system. As this Target List was drawn up in 1981, specification for 1982 MY cars were based on popularity of models and engines in the 1981 MY.

5.0 VEHICLE ACQUISITION AND TEST FLEETS

5.1 Soliciting and Incentives

Using the Target List 200 supplemented by information on preferred mileage, typical car models and reference manuals (for decoding the vehicle identification number VIN), a project technician started searching for suitable cars on large parking lots in the Metro area (mainly at shopping malls and company parking lots).

When spotted, a prospective car was checked for MY by noting the VIN, then it was quickly looked over for signs of wear (tires, tail pipe). Then a numbered invitational letter in a sealed MOE envelope was left under the windshield wiper. The letter and the envelope were marked by the vehicle licence number to prevent unauthorized transfer to some other vehicle and to avoid confusion with mass-distributed promotional materials (garbage-mail). (Typical letters are shown in Attach: B1 and B2). The form of the letter was changed several times (usually after a period of poor response), but the basic message stayed essentially the same: "MOE would appreciate cooperation in testing the car for emissions and promises compensation for its use".

Despite these precautions, only one in approximately 10 car owners responded by calling back. (Note: In EPA 77 FY program there were 30 mailings per car, L17). The calls were handled by the project technician, who explained briefly the purpose and type of test, time frame, compensation and answered all questions. The car owner was then briefly queried about state of brakes, possible leakage of exhaust system and about occurrence of black smoke.

Compensation for the 1½-day inconvenience (including gasoline consumed) was based very approximately on commercial rental rates. It was fairly modest and paid by cheque usually within two months (see Table 5.1 - 1).

If agreement was reached at the end of the first telephone interview, the car was either scheduled for an emission test within the next 2-3 weeks, or put on a waiting list.

Table 5.1 - 1

Rental Fee Structure ($ per 2-day test)

Fee Structure	Model Year	Car Size S	C	M	F
Before Aug. 1982	76 & newer	50	60	70	80
	75 & older	40	40	50	60
After July 1982	79 & newer	70	70	80	90
	78 & older	50	50	60	70

Note: Incentive package provided by U.S. contractors working for EPA is much more generous: $50 U.S. Savings Bond, a late model courtesy car (for 2 days) including free fuel, and a full tank of fuel for the test vehicle (L17).

In the case of a fairly old vehicle (approximately 1974 MY and older), a separate pre-inspection was usually arranged for (1-2 weeks before test date), during which the mechanical condition of the car was examined more closely. Cars with faulty brakes, leaky exhaust systems, with serious smoke problems, with worn or damaged tires, or having unusually high (or low) mileage readings were rejected. When preinspection was necessary, the rental fee was increased by $30. Owners of cars scheduled for testing were always requested to deliver vehicles with at least half a tank of gasoline (same brand and type as normally used by owner).

5.2 Handling

On the first test day (Wednesday for the first test car or Thursday for the second), the test vehicle was either picked up by the project technician (at an agreed upon location) or delivered by the owner to the MOE Test Centre (at 1146 Castlefield Avenue, Toronto, Ontario) usually between 8:00 a.m. to 11:00 a.m.

(a) Activities at Castlefield TC - in Owner's Presence

- checking of brakes for proper function
- checking of exhaust for visible emissions (smoke)
- all-around inspection of car's exterior/interior (all damages, scratches were noted on Vehicle Inspection Sheet, see Attach. B3 and B4)
- completion of Agreement (see Attach. B5 and B6)
- completion of Questionnaire (see Attach. B7 and B8) showing vehicle usage and maintenance
- conclusion of taking-over formalities
- owner given ride to work, home or public transportation (optional)

(b) Activities at Castlefield TC - in Owner's Absence

- Idles Test performed 3 to 5 times with the vehicle at normal operating temperature, using an infra-red HC/CO analyzer
- establish compliance with Ontario emission standards at Idle and Fast Idle (2500 RPM)
- inspection under hood: checking of main exhaust emission system (missing or non-functioning parts were also noted, e.g., seized air pump); checking of compliance labels (to determine whether US- or Canada-specification car)
- checking of levels of liquids (motor oil, coolant, transmission and brake fluids, gasoline)
- checking of exhaust system for leaks (on a hoist, using HC detector)
- checking of car's trunk for excessive load and weighing of vehicle to ± 10 lbs
- departure for Downsview TC (at approximately 1:30 p.m.)

(c) Activities at Downsview TC - First Day

- checking of car by DTC test staff (noting of additional information re: tires, carburetor, VIN, mileage)
- inflation of tires on driven wheels to 45 psi

- setting of inertia weight (according to loaded vehicle weight)
- preconditioning (using prescribed FTP-75 cycle, i.e. 1372 seconds)
- driving off the dyno, closing the hood and soaking of vehicle at 68-86°F (20-30°C) for 12 to 36 hours.

(Note: Should the car have failed any of the above mentioned checks and tests, a substitute car was acquired from car rentals, available govt. vehicles or a used car dealer - depending when failure occurred).

(d) Activities at Downsview TC - Second Day

- after dynamometer warm-up and calibration, the test car was pushed onto dyno and driven through prescribed FTP-75 test cycle;
- after another soak period of approximately 1 to 2 hours, a MFTP-75 test cycle was run;
- deflation of tires to normal pressure
- pick-up of test car by project technician (around 12:30)

Test car was then delivered to owner. A second inspection of car's exterior/interior was performed and a Release Form (see Attach. B9) signed by owner. A payment of rental fee was then initiated. (Note: In a few cases, minor damages to test cars occurred while in MOE possession, involving wheel cover, scratches, tires, outside mirror, etc. None of these claims exceeded $120 and they were settled to owners satisfaction within two months). About a week after the test a Thank You letter was mailed.

In less than 20 instances retests were performed at a later date (when part of analytical equipment was not working the first time, e.g. NO_x analyzer, or when results of the first test were made void, e.g. due to suspicion of a calibration error).

5.3 Insurance

All vehicles rented for test purposes were covered by a Standard Garage Automobile Policy for third party liability, collision and specified perils. This insurance, covering test vehicles while in MOE possession, was deemed necessary due to the fact that regular owner's insurance was voided as a result of renting the vehicle for a fee. Insurance premiums, $15 per car, were paid by MOE.

5.4 Test Fleets A-D

Between August 1979 and June 22, 1984, 374 cars were tested, not including retests. (Note: Table 2.5 - 2 covers the test period until the end of August 1984).

(a) Fleet A - consists of 295 cars of 1962-1984 MY. It represents what is called Wider Ontario Sample - WOS 295. Included in Fleet A are all cars tested between August 79 - June 84, except those cars or test results, that were deemed atypical or incomplete. (These were put into Fleet C or D, respectively).

(b) Fleet B - is a subset of Fleet A. It consists of 197 cars of 1962-1982 MY, that closely match specifications of the Target List 200. This fleet represents the Ontario car population as of mid-1982. (Note: While 6 cars were specified in the 1962-67 MY group, only three testworthy cars have been found and tested. To be able to complete and evaluate the Ontario Sample 200, these three cars were represented twice).

(c) Fleet C - consists of 52 high-mileage police and government cars of 1974-1979 MY. These were tested at the outset of the test program in 1979-80 to establish test routines and to investigate the correlation between cold-start FTP-75 and hot-start MFTP-75.

(d) Fleet D - consist of 11 cars:

- 2 cars operating solely on propane
- 3 government cars tested repeatedly in the beginning of the test program.
- 6 cars tested in hot-start (MFTP-75) only.

(e) In addition to these fleets (A, C, D) another 16 cars were tested, the results of which were subsequently discarded due to suspected CVS or calibration problems.

6.0 TEST FACILITIES

6.1 Locations and Layout

Downsview Test Centre - DTC, where FTP-75 and MFTP-75 tests were performed, is located in the MTC complex at 1201 Wilson Avenue, Downsview, Ontario, M3M 1J8, (416) 248-3404. (Elevation above sea level :525 feet.)

Castlefield Test Centre - CTC, where the Idles Tests were performed is located in the MOE building at 1146 Castlefield Avenue, Toronto, Ontario, M6B 1E9, (416) 965-4159. (Elevation above sea level :565 feet.)

Note: If not mentioned otherwise, the equipment described in detail below is located and being used at the Downsview TC.

DTC has been housed in a rather small self-contained bay in an older MTC building. This imposed limits on the total size, shape and accessibility of the test facility. The basic layout of the DTC is shown in Fig. 6.1 - 1 (L12). A total enclosed area of 1270 sq. ft. (53 x 24 ft, i.e., 16.0 x 7.3 m) has been subdivided into three rooms: test bay, instrumentation room and gas storage.

- Test bay in Figure 6.1 - 2, contains:
  - chassis dynamometer (incl. driver's aid)
  - Constant Volume Sampler (CVS)
  - air compressor
  - cooling air fan with ducts
  - exhaust disposal hoses
  - other paraphernalia like fire detection and extinguishing system, calibration instruments, storage racks

- Instrumentation room, in Figure 6.1 - 3, contains:
  - dynamometer control desk
  - CVS control box and six sampling bags
  - analytical console (outlets)
  - gas distribution network
  - computer, data collection system, printer
  - other equipment such as: calibration equipment, circuit breakers, storage racks, desks, filing cabinets

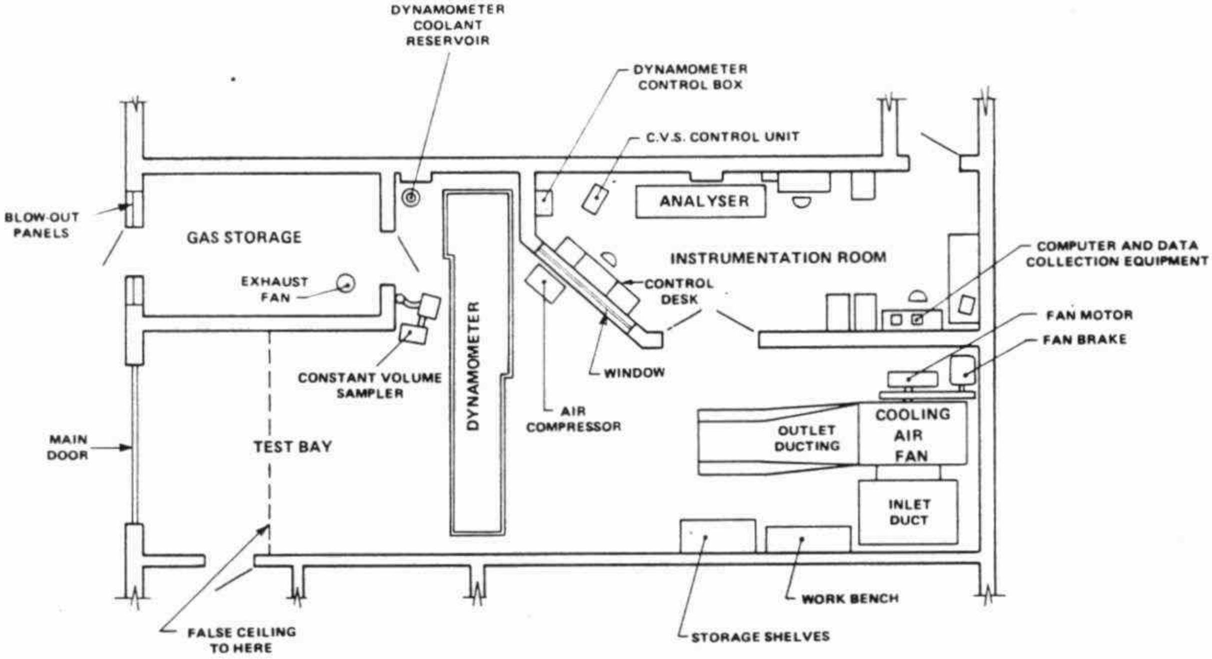


Fig. 6.1 - 1: Plan of testing facility

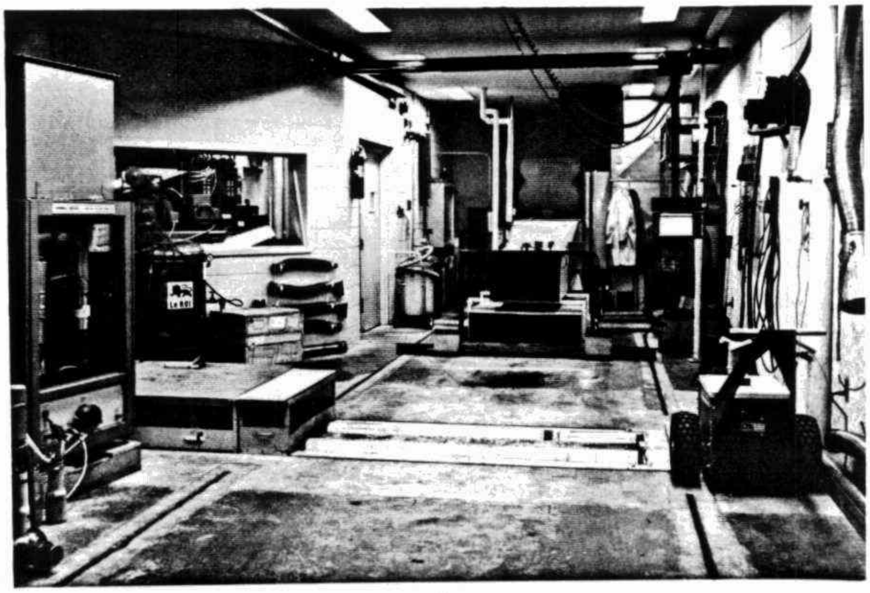


Fig. 6.1 - 2: View of test bay: Constant Volume Sampler (left),instrumentation room,cooling fan (centre) and dynamometer (in a pit),battery-powered push-cart (right).

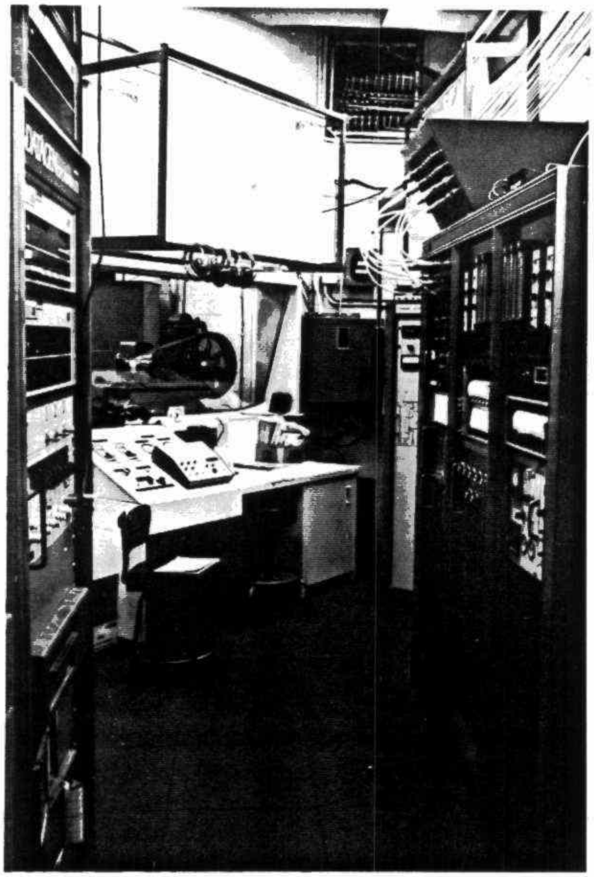


Fig. 6.1 - 3: View of the instrumentation room: computer (left), dyno control desk, analytical console (right).

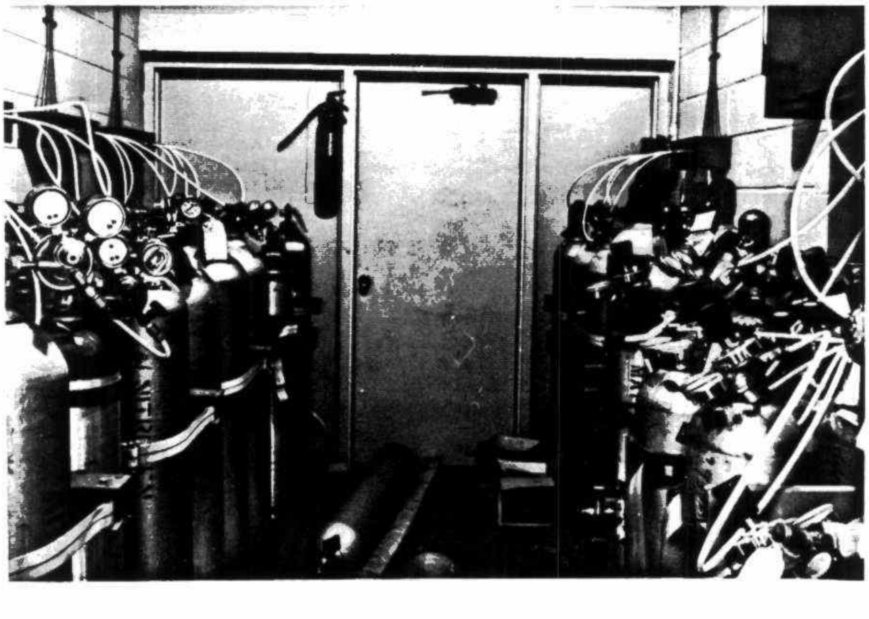


Fig. 6.1 - 4: Gas Storage Room (with inlets to gas distribution network,on the walls).

- Gas storage room, in Figure 6.1 - 4, contains over 80 cylinders of size 1A or 2 with:
  - working gases (N_2, air, oxygen, H_2/N_2)
  - primary and secondary calibration gases (in racks)
  - regulators
  - gas distribution network (inlets)
  - empty cylinders

The principal components of the above test facility (such as dynamometer, CVS, analytical console, calibration gases and equipment) meet the requirements of the U.S. Federal Register, Title 40, Part 86 and of regulations issued under the Canada Motor Vehicle Safety Act, 1970 (L43).

6.2 Chassis Dynamometer

A two-roll Clayton ECE50 chassis dynamometer has been installed by MTC. It is equipped with a hydraulic power absorption unit (up to 50 HP) and eight fly-wheels, which make it possible to simulate inertia of vehicles between 1000 to 8875 lbs (454 to 4026 kg), in increments of 125 lbs. Dyno rolls are 8.65 in (220 mm) diameter and 77 in (1960 mm) long, allowing speeds of up to 90 mph (see Fig. 6.1 - 2).

Dyno warm-up is done by means of an electric motor drive system, which was specially created by MTC. (A warm-up procedure using a non-research vehicle could not be followed due to the fact that the soak area accommodates only one vehicle, the test car). Inertia setting for each vehicle is based on actual curb weight (established by weighing), to which 300 lbs are added to compensate for occupants and luggage. Power setting is based on a coast-down from 52 to 48 mph, which is evaluated by computer.

6.3 Constant Volume Sampler - CVS

A constant volume sampler made by Horiba, Model 20 CVS, has been provided by MOE. It is of the modular type and consists of four units:

- Sampler unit, which is located in the test bay and shown in Fig. 6.3-1, contains ambient air filters, mixing duct, cyclonic separator, sampling venturi, main critical flow venturi (rated at 350 cfm) and a venturi inlet pressure transducer. The unit is connected to a:

- Blower unit, also located in test bay, which contains a Spencer turbo-compressor model 2007-H, 7.5 HP, rated for 400 cfm flow at 4 in. of mercury inlet vacuum. Diluted exhaust is discharged through a duct and an 8 ft. stack;

- Control unit, in Fig. 6.3-2, located in the instrumentation room. It contains sample filter (7 cm, fliptop), sample pumps (bellows type, for dilute sample and for ambient sample), 24 two-way normally closed solenoid valves, sample flowmeters.

- Sample storage unit, in Fig. 6.3 - 3, located in the instrumentation room. It contains six Tedlar bags (2 mil thick), each holding 4 cu.ft. of sample gas.

6.4 Emission Analysis Console

A custom-designed analytical console was manufactured by Analygas Systems Limited, Ontario, based on MOE specifications, see Figure 6.4 - 1. It follows the flow schematic specified by Canada Motor Vehicle Safety Test Methods, Fig. 1(b) (L43). It contains the following analytical instruments (oriented to analysis of diluted exhaust gases from bags or continuous sampling):

Low-CO	Horiba AIA-23 (AS) NDIR Dual detector Analyzer, with OPE-115 Electronic Module and 2 linearization circuits (NOR-4A Analog Linearizer Boards). Four Ranges: 0-100 ppm, 0-500, 0-1000 and 0-5000 ppm.
High-CO	Horiba AIA-23 NDIR Single detector Analyzer, with OPE-115 Electronic Module and a NOR-4A Analog Linearizer Board, with two ranges: 0-1%, and 0-4%, vol. CO.

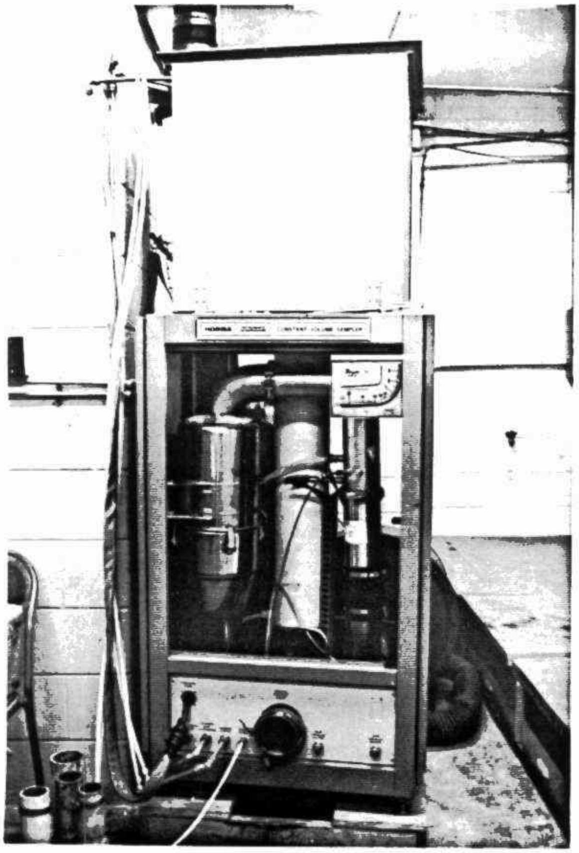


Fig. 6.3 - 1: Constant Volume Sampler -CVS (Sampler Unit).

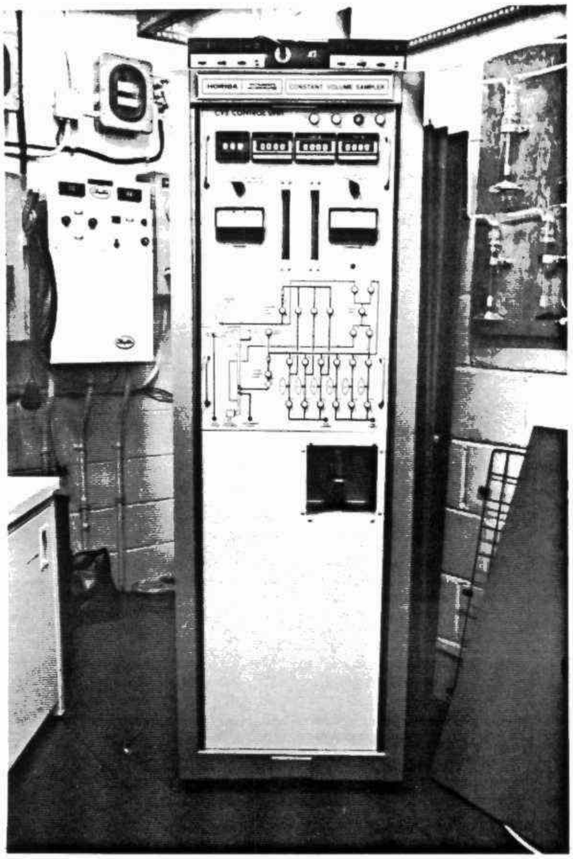


Fig. 6.3 - 2: Constant Volume Sampler -CVS (Control Unit).

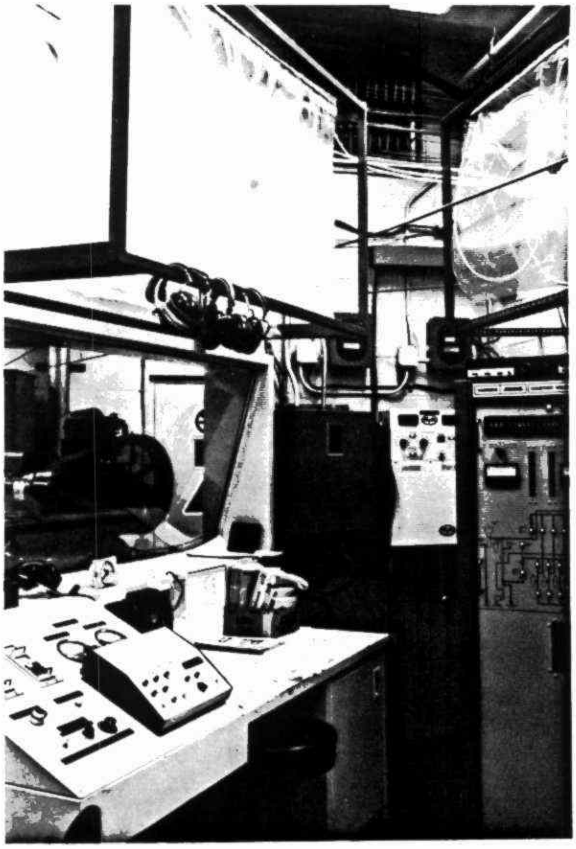


Fig. 6.3 - 3: Instrumentation Room: dyno control desk, sample collection bags (above), CVS-control unit (right).

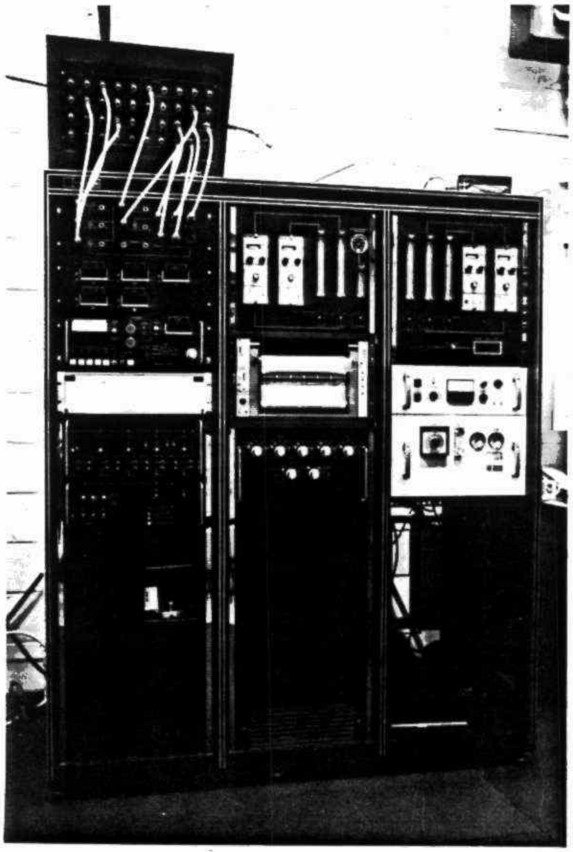


Fig. 6.4 - 1: Analytical Console (with outlet panel of the gas distribution network, above).

CO_2	Horiba AIA-23 NDIR Single detector Analyzer, with OPE-115 Electronic Module and two NOR4A Analog Linearizer Boards, covering four ranges: 0-0.6%, 0-1.5%, 0-3.0%, and 0-7.5% vol. CO_2.
HC	Horiba FIA-21 FID Analyzer, with OPE-405 Electronic Electronic Module, with eight ranges: 0-10, 30, 100, 300, 1000, 3000, 10,000 and 30,000 ppm THC (carbon). Uses 40% H_2/60% N_2 fuel mixture.
HC (back-up)	Beckman 400, FID Analyzer with four ranges: 0-100, 1000, 10000 and 100000 ppm THC (carbon). Uses 40% H_2/60% N_2 fuel mixture.
NO_x	Beckman 951A, NO/NO_x Chemiluminescence Analyzer with seven ranges: 0-10, 25, 100, 250, 1000, 2500, 10000 ppm NO_x.

The sample of gas from the collection bags is filtered using a 7-cm flip-top stainless steel filter (glass-fibre paper Whatman GF/A), then it flows into a pressurized manifold, and from there into individual analyzers. Inlets to each analyzer are controlled by a series of solenoid valves: INLET (which could be either from sample bags, or continuously diluted sample or room air or N_2 purge), SPAN gas #1, SPAN gas #2 and ZERO gas. For each instrument and range being used there are two span gases constantly on tap, which enables fast spanning and span check. Should a switch to a different range be necessary, span gases can be changed very quickly by using quick-disconnects on the outlet panel (shown above the analytical console in Fig. 6.4-1). The outlet panel features 40 outlets which permit the operator quick access to 34 different span gases. Six more outlets are reserved for: N_2, zero air, fuel gas (H_2/N_2) and oxygen. All plumbing, valves and fittings in the analytical console, in sample and gas distribution networks is either stainless steel or teflon.

6.5 Calibration Gases and Quality Assurance

6.5.1 Calibration Gases

Calibration gases of two grades (supplied by Matheson, Whitby, Ont.) were used to calibrate analytical instruments on a daily basis:

(a) Primary standards with certification accuracy of ± 1% rel. of the component or ± 0.02% v. absolute, whichever was smaller. These mixtures were blended by weighing the gas components on a high-load, high-sensitivity analytical balance using weights traceable to National Bureau of Standards (NBS). Subsequently they were analyzed by the manufacturer using gas mixtures traceable to NBS.

(b) Certified standards with certification accuracy of ± 2% rel. of the component.

On arrival, new gas mixtures were checked against old stock, against cross-reference samples supplied by Scott Environmental Technology (Plumsteadville, Pa. 18949) and from time to time directly against NBS gases. Gases were then named in agreement with these analyses.

Concentrations of calibration gases used at Downsview TC are shown below:

HC (in ppm C), consisting of propane in zero air

9.00
9.21
25.08
26.97
88.5
89.73
269.7
899.1
9420
27080

CO (in ppm and % vol.), consisting of CO in zero nitrogen

10.3
25.8
46.2
66.7
93.6
94.8
200.0
267.0
323.0
459.5
482.0
650.0
750.0
899.9
1600.0
3002.0
4599.0
0.233
0.434
0.80
0.90
0.975
0.980
1.37
1.96
3.57
3.93

NO_x in (ppm), consisting of NO in zero nitrogen

9.71	139.3	950
25.7	219.7	2290
90.1	888	

Other Working Gases

N_2	Nitrogen, UHP
Air	Air, Vehicle Emission Zero Gas
O_2	Oxygen, UHP
H_2/N_2	40% Hydrogen, 60% Nitrogen
Propane	Propane C.P. (99.5%)
CO	Carbon Monoxide, C.P.

CO_2 (in % vol.), consisting of CO_2 in zero nitrogen

0.09	0.999	5.00
0.300	1.40	7.00
0.499	2.899	7.40
0.500	2.92	15.1
0.77		

The following certified mixtures were used to calibrate garage type HC/CO analyzers (located at the Castlefield TC):

HC/CO (in ppm; % v.), consisting of propane and CO in zero nitrogen

796 and 1.94	2534 and 5.55
966 and 2.06	

HC (in ppm), consisting of propane in zero nitrogen

406	1825
538	

CO (% v.), consisting of CO in zero nitrogen

1.98	5.4

CO/CO_2 (in % v.), consisting of CO and CO_2 in zero nitrogen

0.398 and 8.02

CO_2 (in v.), consisting of CO_2 in zero nitrogen

7.9

Note: A factor of 0.525 was used to convert propane concentrations to hexane values needed for calibration of the garage-type HC/CO analyzers.

6.5.2 Calibrations and Quality Assurance

Dynamometer: A warm-up of the dynamometer was performed before commencing the first cold-start test to warm up the bearings and stabilize the friction losses. For this purpose the dyno was permanently equipped with an electric motor drive and clutch. Warm up took approximately 20 minutes and was done as the first thing in the morning.

A dynamometer calibration using the coast-down method was performed every morning. (Since early 1981 the dyno calibration and operation has been computer controlled). A very thorough dyno calibration, including checks using a stroboscope light, was performed every four weeks or when indicated.

CVS: Flow calibration using the LFE, set of sensitive waterfilled manometers and a leak test were performed on a weekly basis. A propane injection test using CFO was performed every 2-4 weeks, or as needed, with a target for propane recovery of ±2% of injected mass. A CO injection test was performed on an irregular basis.

The CVS sample bags were filled with N_2, evacuated and leak tested prior to each test.

Analytical Console: Calibration curves of HC, CO, CO_2 and NO_x analyzers were checked each week, and linearizers adjusted, if necessary. Curves were established using a set of primary and certified standards, and by means of a gas divider (based on mass flow controllers or capillaries). Usually up to seven points were checked on each range of the CO and CO_2 analyzers, and three points on HC and NO_x analyzers.

Zero and span gases (in the 80-90% area of each range) were used just prior to and following the sample analysis. Converter efficiency of the NO_x analyzer was maintained above 90% (L46).

Collaborative Analysis: A comparison of analytical results with approximately 50 emission testing laboratories in the U.S., Europe and Japan was routinely established every three months through a collaborative gas analysis Cross Reference Service (by Scott Environmental Technology Inc., Plumsteadville, Pa. 18949). Under this service unknown mixtures of: (a) HC (propane), CO and CO_2 in air (Service C-CVS), and (b) NO and NO_x in nitrogen (Service E1) are independently analyzed by each participating laboratory. All reported results are then statistically evaluated by Scott's (after elimination of outlying values, i.e. those that deviate from the mean by more than ±3 S.D.), in terms of minimum, maximum, mean and median values, estimates of standard deviation and of standard error, and coefficient of variance (all of these values being calculated for each component).

Analytical results of the Downsview TC compared favourably with other laboratories on the circuit, such as VW of America (California), American Honda, American Motors Corp., California Air Resources Board. Quarterly results for 1984, (in % rel. deviation from the means of 29 to 45 laboratories) are as follows:

Quarterly Sample	HC	CO	CO_2	NO	NO_x
I/84	-.35	+2.42	+.25	- .13	- .08
II/84	-.06	+ .61	-.35	+1.71	+2.46
III/84	-.17	- .43	-.67	+ .70	+1.49
IV/84	+.88	-1.17	-.27	- .82	- .74

Note: It is normal for these deviations to be between +3% to -3%. The best laboratories (like Calif. ARB) usually fluctuate in the +1.2% to -1.2% range.

6.5.3 Repetitive Testing of Cars

One of the tools employed by large emission testing laboratories (such as EPA and GM, see L44) in order to prove the integrity of their emission measurements is a repeatable car or repcar. It is a car with greatly modified carburetor, ignition, accessories, brakes, engine, emission control systems and fuel supply. Compared to a standard vehicle, the repcar shows a substantial reduction in variability of test results. In many cases, such a repcar is used to compare test sites (within one laboratory), or even to compare laboratories. Also, it helps to diagnose and solve variability problems.

In 1979-80, MTC made an effort to prepare and repeatedly test such a repcar (based on a 1974 MY car). The results were generally disappointing, as the variability of the car (despite extensive engine and system modifications) was not much better then that of standard, unmodified cars. Discussions with Environment Canada in Ottawa confirmed similar problems there.

In 1980, eight series of tests were run by MTC on four standard (i.e., unmodified) cars of 1975-78 MY. The cars were first tested cold-start and cold-start and then repeatedly (6-12 times) using the hot-start MFTP-75 test; all on the same day, with ten minutes soak periods in between the tests. These results (shown in Table 6.5 - 1) were more repetitive than previous results with the MTC repcar.

Table 6.5 - 1

Lowest Coefficients of Variation (C.V)
in Repetitive MFTP-75 Tests
(8 series of tests, 4 cars, 1975-78MY)(1)

Variable (= phase of MFTP-75)	Coefficient of Variation (C.V. = 100 S.D./Mean)		Mean Emissions (in g/mi) and FC (litres per 100 km) corresponding to the	
	Lowest C.V. % (2)	Second Lowest C.V. %	Lowest C.V.	Second Lowest C.V.
HCTBHOT	4.4	5.2	1.8	1.8
HCTBSTAB	.9	1.5	2.3	.5
COTBHOT	3.9	4.3	49.9	20.2
COTBSTAB	3.4	4.5	28.1	35.3
NOTBHOT	.5	2.9	4.4	3.2
NOTBSTAB	1.6	2.0	1.9	1.8
FCTBHOT	.2	.3	19.5	14.3
FCTABSTAB	.5	.5	21.8	15.8

Notes (1) A total of 8 series of hot-start MFTP-75 tests were performed on 4 cars:

Car A: 78 Chev-Impala, 305 CID, V8, A3, 2-bbl, with CAT (3 series: 12,6 and 12 tests)

Car B: 78 Chry-New Yorker, 440 CID, V8, A3, with MOD-Lean Burn (2 series: 6 and 6 tests)

Car C: 78 Chev-Bel Air, 350 CID, V8, A3, 2-bbl, with CAT (1 series of 12 tests)

Car D: 75 Chry-Newport, 400 CID, V8, A3, 4-bbl, with MOD (2 series: 8 and 7 tests).

(2) C.V. for each series (of 6-12 tests) was evaluated, and the lowest value of C.V. of all 8 series is shown in this column.

Since 1980, the lack of a repcar has been overcome by closely scrutinizing all repeat tests produced by MTC under the Transportation Energy Management and the Alternate Fuel Research programs. Under these programs a relatively small fleet of vehicles (15-20) has been tested repeatedly with different adjustments or fuels. It is usual to establish one point by testing the vehicle two or three times (while keeping all variables constant). Variations in emissions and in fuel economy during these two or three tests were closely watched.

In addition to this effort, results from MFTP-75 tests that are available for all vehicles tested by MOE are used in conjunction with individual bag results from FTP-75 as an indicator of repeatability of tests.

6.6 Computer and Auxiliary Equipment

6.6.1 Computer System (on-site)

- A desk-top Hewlett-Packard 9825A computer with an HP 2631 printer, HP 2621A CRT display and keyboard, HP 9878 I/O expander (incl. HP 98035a real-time clock) are used to:
  (a) trace out different cycles on a strip chart recorder (driver's aid),
  (b) manipulate, calculate and present car and test data,
  (c) store and retrieve data.
- Two flexible disk drives, HP 9885M master and HP 9885S slave are used for mass information storage.
- An NEFF 600 data acquisition system, with NEFF 300 signal conditioner and NEFF 100 amplifier (multiplexer) is also available.

6.6.2 Auxiliary Calibration Equipment

- Laminar Flow Element - LFE, by Meriam Instruments Co., Cleveland, Ohio, Model 50 MC 2-4, is used to calibrate the flow through the CVS. LFE was calibrated for air at 400 CFM and 8 in. H_2O, 70°F and 29.92 in. Hg absolute.
- Water-filled manometers (4), all by Meriam Instruments Co., Cleveland, Ohio, have been used in conjunction with the above LFE: (a) Inclined manometer, 10 in./40 in., Model 40 HE35WM, (b) 40 in. manometer, Model 30EB25WM, (c) 60 in. manometers, Model 30EB25WM.

- Critical Flow Orifice - CFO, Horiba Model 201, has been used to calibrate CVS system by injecting known quantity of pure propane (99.5%) or CO (C.P.).

- Standard Gas Divider - SGD, by Standard Technology Inc. Japan, Model SGD - 78C - 5L with 9 preset and calibrated divisions (capillary-based), better than 0.5% accuracy in the 0°-40°C range has been used to calibrate individual ranges of HC, CO, CO_2 and NO_x analyzers in the console.

- NO_x Generator, Thermo Electron, Model 100 has been used to check efficiency of converter in the NO_x analyzer.

7.0 TEST PROCEDURES

7.1 Idles Test (Raw Exhaust)

During the initial handling of each test car at Castlefield Test Centre - CTC (as described above in Section 5.2), a two-speed Idles Test was performed using a garage-type HC/CO infrared analyzer. One of the three available SUN - Exhaust Performance Analysers, Model EPA-75 (made by SUN Electric Corp., Chicago, Illinois) was used. These instruments analyze for HC (as n-hexane): in 0-500 ppm or 0-2000 ppm ranges and for CO: in 0-2.5% v. or 0-10% v. ranges. (Their water-separation and filtration systems were substantially modified by MOE for the purposes of the Ontario spot-checking program). Analyzers were calibrated mechanically before each test, and every week they were checked for response to calibration gases (see Section 6.5.1).

Cars were tested at operating temperature in Idle (Neutral) and in Fast Idle (i.e. at 2500 ± 50 RPM). Stabilized readings of HC and CO were recorded and the procedure repeated 3 - 5 times.

7.2 Preparation and Preconditioning

On arrival at Downsview TC, usually around 1.00-2.00 p.m., the car was checked by DTC test staff for safety (brakes, tires), exhaust leaks, and additional detailed information (re: tires, carburetor) was entered into the test record. Before setting up the car on the dyno, the active tires were inflated to 45 psi and inertia weight was set. While on the dyno, a restraint system was applied: two wedges were positioned approximately one inch in front of the non-active wheels. Additional restraints were used on front-wheel drive cars to prevent transverse movement of front of car.

As all vehicles were to be tested in as-received condition, no adjustments or tune-ups were performed prior to the tests. Also, cars were tested using the fuel supplied with them (i.e. fuel tanks were not drained and uniform test fuel like Indolene was not used). Original tires (even if snow tires) were used, providing they were deemed safe.

Test vehicle was then preconditioned by driving it on the dyno through the transient part of the cycle (505 seconds covering approximately 3.59 miles) and stabilized part (867 seconds covering approximately 3.86 miles), generally in accordance with Canada Motor Vehicle Safety Test Methods, (L43) and U.S. Federal Register, Title 40, Part 86 (L45). (During preconditioning, the exhaust gases were picked up by a raw exhaust disposal system using 1-2 flexible hoses of 5 inch diameter and a 1060 CFM exhaust fan. Gases were then released through a stack on the roof).

7.3 FTP-75 Test (Cold-start, EPA Urban, 3-bag Test)

The following morning (usually between 8:30-10:00 a.m.) after warm-up of the dyno by a built-in electric motor, after prescribed calibrations and after pushing the test vehicle back onto the dyno, a FTP-75 test was performed (on all test vehicles regardless of their model years). The FTP-75 test is also called cold-start, EPA Urban, CVS-2 or 3-BAG Test. It consists of three parts: in each part a separate bag is used to collect diluted exhaust gases (sampled by CVS), while another bag is being filled with a sample of ambient air used for dilution. The cycle (i.e. speed sequence) follows the EPA Urban Dynamometer Driving Schedule simulates a 7.5 miles sub-urban trip.

Table 7.3 - 1

FTP-75 (EPA URBAN TEST)

No. Bag (sec.)	Phase corresponding (sec)	Time #	Duration SAS variable	Exhaust	Name of the
1	Cold-transient	0-505	505	1	EPCOLD
2	Cold-stabilized	505-1372	867	2	EPSTAB
3	Soak	10 minutes	600	-	-
4	Hot-transient	0-505	505	3	EPHOT

These phases of the FTP-75 cycle are usually referred to in brief as: COLD, STABILIZED, SOAK and HOT.

After each phase, the actual distance counter and the CVS volume counter were read and recorded. The exhaust (and ambient bags) were analyzed after each phase or during SOAK. After completion of the FTP-75 test, the test vehicle was allowed to soak (with engine off and hood closed) for another 1 to 1½ hours. This period was meant to simulate time needed to prepare a warmed-up vehicle for a hot-start test, MFTP-75.

7.4 MFTP-75 Test (Hot-start, DYN 9, 2-bag Test)

The MFTP-75 (which stands for Modified FTP-75) was designed by MOE in 1979 with several objectives in mind:

(a) to provide partial confirmation of FTP-75 results,

(b) to develop a shorter (1-day, hot-start) test which would correlate well with FTP-75 and could be used in the future as an occasional substitute for FTP-75 in certain applications,

(c) to provide an emergency test, which would be available for those cases when a proper FTP-75 was aborted or could not be run at all (i.e., as a test-time saving measure),

(d) to provide information on repeatability of test results (missing due to lack of repcar).

Note: EPA Highway Fuel Economy Test - HFET was considered for these purposes, but rejected as it would not meet most of the objectives.

MFTP-75 uses the same speed vs. time sequence as specified for the FTP-75 (Urban) test. It starts with a partially warmed-up vehicle (the operating temperatures of which are not well defined), which is not expected to be available for the cold-start FTP-75, including the necessary preconditioning and overnight soak.

Preconditioning of the car for the MFTP-75 is done by driving for 1372 sec (7.5 miles) through the Urban Driving Schedule. No samples are taken. Then after a ten minute SOAK, the hot and stabilized phases are run and sampled, as shown in Table 7.4 - 1 (L47).

In subsequent correlations, it is assumed that Bag 4 (TBHOT) correlates with Bag 3 (EPHOT) and that Bag 5 (TBSTAB) correlates with Bag 2 (EPSTAB). (Note: The underlying assumption that cold-stabilized phase is identical to hot-stabilized phase has already been made by EPA and constitutes the basic philosophy behind the FTP-75 test.)

All test cars, except six, were put through FTP-75 and, after approximately 1 1/2 hours of soak, through MFTP-75. In six cases, FTP-75 was either aborted or not run at all. These six cars with hot-start MFTP-75 test only, are mentioned in Section 5.4, in Fleet D.

After these tests, tires were deflated to normal pressure and the car was picked up by the project technician. Following the procedures described in Sect. 5.2 (d), it was then returned to owner.

Table 7.4 - 1

MFTP-75 (TWO-BAG TEST)

No.	Phase	Time (sec.)	Duration (sec.)	Exhaust Bag #	Name of the corresponding SAS variable
1	Precond.-transient	0-505	505	-	-
2	Precond.-stabilized	505-1372	867	-	-
3	Soak	10 minutes	600	-	-
4	Hot-transient	0-505	505	4	TBHOT
5	Hot-stabilized	505-1372	867	5	TBSTAB

8.0 DATA COLLECTION AND EVALUATION PROCEDURES

8.1 Collection and Handling of Data

Various forms were used at different stages of inspection and testing to record relevant information and results:

	Form/Sheet	Contains mainly information on
1.	MOE-Vehicle Inspection	Vehicle, engine, owner, emission control system, idle test results.
2.	MOE - Questionnaire	Vehicle usage and maintenance.
3.	MTC - Vehicle Data (DYN 1 - Sheet 1)	Test type, soak, vehicle, tires, engine, inertia, test cell.
4.	MTC - Exhaust Emissions Analysis (DYN 1 - Sheet 2)	Test cell, CVS volumes, distance driven, or dyno, analyzers and ranges used to analyze diluted exhaust and ambient air.

Before further processing, the raw data recorded in these sheets were checked for their completeness, consistency and reasonableness. Data from DYN 1 - Sheet 2 were then used as input into computer to calculate emission results and fuel economy (based on carbon balance).

8.2 Calculation of Results

Results of the mass-emission tests (FTP-75 and MFTP-75) were calculated using equations recommended by EPA (L45) and Transport Canada (L43). Two print-outs were obtained, one for FTP-75 (EPA Urban Cycle), and another for MFTP-75 (Two Bag Cycle). Printouts show results of individual test phases (bags) as well as weighted results for each cycle:

(a) Emissions (of HC, CO, CO_2 and NO_X) in:
- grams per test phase
- grams per mile (actual measured distance)
- grams per mile (EPA distance)

(b) Fuel Consumption (based on carbon-balanc litres per 100 kilometers:
- FC (actual distance)
- FC (EPA distance)

As is usual, the weighting factors used for FTP-75 were: 0.43 for cold-transient phase and 0.57 for hot-transient phase.

Results (FTP-75, MFTP-75) based on actual measured distance were used as representative (after being checked against those based on EPA distance), see further Chapter 8.4. Results of the Idles Test are reported as measured (in ppm HC, %v. CO).

8.3 Data Processing

Basic information on test car, inertia, engine, transmission, emission control system, emissions (in Idles, FTP75 and MFTP-75, both weighted and by individual phases of each cycle), compliance with Ontario and Canada standards and on fuel economy was extracted from test forms and print-outs, coded (if necessary) and transferred to two 80-column punch-cards (A & B). From this point on, test data were handled by a specially designed Statistical Analysis System (SAS) package, using ARB electronic data processing facility (card reader, printer) and the time-sharing option of the MTC Downsview Computer Centre.

8.4 Statistical Analysis System (SAS)

SAS is a computer system for data analysis (L48-50). It runs on IBM 360/370 computers and provides data storage, retrieval, modifications, statistical analysis and custom-report writing. It is highly user-friendly, provides a great choice of procedures, which can all be run from the same data base in a single job (and at a very low cost). The older version of SAS is 79.5 (i.e. 1979 edition), while the current version is 82.3 (1982 edition).

For the evaluation of Ontario car emission data the following SAS procedures were used:

SAS Procedure	Used for
CARDS	Input of data.
TITLE	Specifying title lines.
DELETE	Selection of data from file.
LIST	Listing of input/sorted data (all or some variables).
SORT	Sorting by one or more variables.
PRINT	Printing of all or some variables.
PLOT	Plotting of one variable against another (using third as symbol).
FREQUENCY	Production of one- to n-way frequency and cross-tabulation tables.
MEANS	Production of simple descriptive statistics for numeric variables.
CORR	Computing of correlation coefficients between variables.
UNIVARIATE	Production of descriptive statistics for numeric variables (including quantiles and normal probability plot).
GLM	General linear modelling, i.e., simple, multiple, polynomial and multivariate regressions.
RSQUARE	All possible regressions for one to approx. 14 independent variables.
STEPWISE	Exploratory analysis (to find which variables should be included in a regression model) using forward or backward stepwise regression.
CANCORR	Analyzing relationship between two sets of variables using canonical correlation.
FACTOR	Performing several types of common factor and component analyses with different rotations.
PRINCOMP	Performing principal component analysis (including eigenvalues and eigenvectors) to detect linear relationships among several quantitative variables.

8.5 SAS Variables and Coding

8.5.1 Variables

Variable names have been chosen using the SAS convention, i.e. maximum eight characters, beginning with a letter. There are 47 variables: of these the first 17 describe test, car or engine parameters and their names are fairly self-explanatory; two variables show CO concentrations in Idle and Fast Idle; five variables show weighted FTP-75 results (and have an ending ...EPWEIG or ...EPWEI, respectively); two variables (CANADA, ONTARIO) show compliance of FTP-75 weighted results with Canada emission standards and of the Idles Test results (CO and HC in ID and FI) with Ontario emission standards. (Note: HC concentrations in Idle and not shown as variables due to lack of space, have been with COIDLE and COFASTID to evaluate compliance in variable ONTARIO). The last 20 variables (4 groups of 5) show mass-emissions or fuel consumption per individual test phase (bags) of FTP-75 and MFTP-75. Again, their names are easy to decipher, the first two characters being pollutant (HC, CO, NO) or fuel consumption (FC), the next two characters showing type of cycle (EP for EPA Urban i.e. FTP-75, TB for Two Bag i.e. MFTP-75), and the remaining 3-4 characters designating the phase of each cycle (i.e. COLD for cold-start transient, STAB for cold- or hot-start stabilized and HOT for hot-start transient). As an example: HCEPSTAB designates HC emissions (in grams per mile) in the stabilized phase of the EPA Urban cycle, while FCTBSTAB means Fuel Consumption (in litres per 100 kilometers) in the stabilized phase of the Two Bag cycle.

8.5.2 Coding

Similar to naming of variables, also the coding has been kept simple and easy to remember, thus reducing frequency of errors while encoding or interpreting (decoding) results. For completeness and consistency, all variables are dealt with below:

VARIABLE	DEFINITION AND CODING		
TESTCAR	Test Car Number (sequential: 0001 to 0390)		
SUBTEST	Test Type:	0	First cold-start test
		1	Retest, cold-start
		2-7	Cold- or hot-start tests
		8-9	Hot-start tests
MTCTEST	MTC Test Number (e.g. 83001 for the first test in 1983 year)		
OWNER	Owner Group:	A	Auction (high-mileage govt. and police cars)
		B	MTC - Bay Street
		C	Company
		D	Dealer
		P	Private
		R	Rental
		V	VEU (MOE)
INERTIA	Weight of dynamometer inertia used during the test, in pounds divided by 10 (e.g. 3500 lbs inertia = 350)		
SPECIF	Emission certification label attached to car:		
		C	Canada
		U	U.S. (49 states)
		T	Tune-up information only
		L	Label only
		Blank	No label available
MANUF	Car manufacturer:		
		10	American Motors (AM)
		20	Chrysler Corp. (CH)
		30	Ford Motor Company (F)
		40	General Motors (GM)
		55	Datsun (= Nissan)
		56	Fiat
		62	Mazda
		72	Toyota
		75	VW-Volkswagen
		81	Honda
		84	Lada (USSR)

CARMODEL	Model of car, such as:		MERC-Cougar, PONT-Catali(na), PLYM-Aspen
BODY	Car body:	P	Pick-up
		V	Van
		W	STW-Station Wagen
		Blank	Car
MODELYR	Model Year (last two digits, e.g. 80 for 1980)		
TRANSM	Transmission type and number of gears, e.g.		
		A3	Automatic, 3-speed
		M5	Manual, 5-speed.
LITRES	Engine size in litres		
CID	Engine Cubic Inch Displacement		
ENGTYPE	Type of engine and number of cylinders, e.g.		
		V8	V-engine, 8-cylinder
		L4	L-(line) engine,4-cylinder
CARBVENT	Carburetor Venturis (barrels):		
		0	Fuel injection/propane
		1	1 venturi (bbl)
		2	2 venturis, etc. up to 4 venturis
MILEAGE	Vehicle Mileage (in thousands of miles)		
EMSYSTEM	Main Emission System & Notes:		
		AIR	Air Injection
		CAT	Catalytic Muffler
		FUEL INJ	Fuel Injection
		MOD	Engine Modification
		-	Defective or Missing
	Attached might be notes such as:		
		ADJU	Adjusted (tuned)
		DEF	Defective or Missing
		LEAN	Lean Burn system
		PROP	Propane-powered
		SOOT	Black smoke emitted
HCEPWEIG COEPWEIG CO2EPWEI NOEPWEIG	Emissions (weighted) in EPA Urban cycle (i.e. FTP-75) in grams per mile.		
FCEPWEIG	Fuel Consumption (weighted) in EPA Urban cycle (FTP75), in litres per 100 kilometers.		

COIDLE COFASTID	Concentrations (in % vol) of CO emitted in Idle and Fast Idle (engine at operating temperature).
CANADA	Compliance with Canada mass-emission standards (for 1975-82 MY) or equivalent values (for 1974 and older MY) shown in Table 10.4-1. For exceedance of HC limit add one point, for CO two points, for NO_x add four points. Thus 0 indicates complete compliance and e.g. 6 indicates failure to meet CO and NO_x limits simultaneously.
ONTARIO	Compliance with Ontario Idles emission criteria (see Table 10.1-9 based on Reg. 311, RRO 1980). For exceedance of HC limit in Idle and/or in Fast Idle add one point, for exceedance of Idle-CO add two points, for Fast Idle-CO add four points. Thus 0 indicates complete compliance, and e.g. 3 indicates failure to meet HC limit in Idle and/or in Fast Idle while also failing to meet CO in Idle. (Note: HC emissions in idles have been evaluated for compliance, but actual concentrations have not been shown in listings).
HCEPCOLD	HC emissions (in grams per mile) per cold-start transient phase (Bag 1) of the EPA Urban cycle.
HCEPSTAB	HC emissions (in grams per mile) per cold-start stabilized phase (Bag 2) of the EPA Urban cycle.
HCEPHOT	HC emissions (in grams per mile) per hot-start (Bag 3) of the EPA Urban cycle.
HCTBHOT	HC emissions (in grams per mile) per hot-start (Bag 4) of the Two-Bag (MFTP-75) cycle.
HCTBSTAB	HC emissions (in grams per mile) per hot-start stabilized phase (Bag 5) of the Two Bag (MFTP-75) cycle.
COEPCOLD COEPSTAB COEPHOT COTBHOT COTBSTAB	CO emissions (in grams per mile) per individual phases of the EPA Urban (FTP-75) cycle or Two Bag (MFTP-75) cycle, respectively, in analogy to HC emissions above.
NOEPCOLD NOEPSTAB NOEPHOT NOTBHOT NOTBSTAB	NO_x emissions (in grams per mile) per individual phases of FTP-75 or MFTP-75 cycles, in analogy to HC and CO emission above

FCEPCOLD	Fuel Consumption (in litres per 100 kilometers) per individual phases of EPA Urban (FTP-75) or Two Bag (MFTP-75) cycles, in analogy to above.
FCEPSTAB	
FCEPHOT	
FCTBHOT	
FCTBSTAB	

Additional variables were derived as needed by manipulation of the above 47 basic variables:

AGE	Test Year minus Model Year
USAGE	e.g. 82 minus Model Year, which shows usage of car (in years) after assuming that all cars were tested in 1982.
HCSDIF	= HCEPSTAB minus HCTBSTAB
COHDIF	= COEPHOT minus COTBHOT, etc., which shows the difference between corresponding EPA Urban and Two-Bag results in S (stabilized) or H (hot) parts of the cycle.

These variable names and codings have then been used consistently in all test data surveys (i.e. listings, tabulations, plots, simple statistics, correlations, regressions, etc.)

9.0 TEST DATA (BY FLEET)

A total of 374 cars were tested between August 1979 and June 22, 1984. Their results are shown and discussed by fleets:

Fleet A	295 cars	Wider Ontario Sample (WOS 295)
Fleet B	(200 cars)	Ontario Sample (OS 200); Subset of Fleet A
Fleet C	52 cars	High-mileage police/government cars
Fleet D	11 cars	Special tests
Fleet E	16 cars	Results discarded
Total	374 cars	

9.1 Fleet A: Wider Ontario Sample - 295

Fleet A consists of 295 cars of the 1962-1984 MY tested until June 1984. It constitutes a broader Ontario data base, and is therefore called Wider Ontario Sample - 295 (WOS 295). While the sample is not, strictly speaking, representative of any particular registration year, it approximates 1983 RY.

From Fleet A, 197 cars were selected as being closely matched with Target List 200. These are dealt with in Section 9.2 (Fleet B). The remaining 98 cars are either 1983-84 models (29 cars) or extra cars (69) tested while filling the Target List 200; these include slightly off-target cars and substitutes (i.e. cars supplied by rental companies, used-car dealers, Ontario Government or private owners on a very short notice in order to make use of available test time).

Complete results of WOS 295 are listed in Table 9.1-1A and 1B in Attach. C. (For coding see Sect. 8.5). Fleet A characteristics by different variables, is shown in Table 9.1-2A.

Table 9.1-2A

Fleet A - Characteristics

MY	62-67	68-70	71-74	75-79	80-82	83-84
%	1.0	2.7	12.2	47.1	27.1	9.9
MANUF.	AM	CH	FO	GM	OTHER	
%	3.4	20.0	17.3	45.1	14.2	
CID	51-140	141-250	251-360	361-470	-	
%	25.8	28.1	42.7	3.4		
CYLIN.	4	6	8	-	-	
%	28.5	26.4	45.1			
MILEAGE (000's)	0-10	11-20	21-40	41-60	61-100	101-200
%	18.0	13.9	22.4	13.9	22.4	9.5
INERTIA (000's)	2-3	3-4	4-5	5-6	-	-
%	25.8	51.2	21.4	1.7		
OWNER	Private	Dealer	Rental	Gov't	-	-
%	74.6	7.1	13.2	5.1		
EM. SYSTEM	MOD	AIR	FUEL INJ	CAT	CAT+AIR	NONE
%	23.1	11.5	2.4	37.3	24.7	1.0
SPECIF.	US	CAN	LABEL	N/A	-	-
%	33.2	27.5	18.3	21.0	-	-

Note: More detailed characteristics by MY including compliance with CANADA and ONTARIO standards are shown in Table 9.1-2B , in App. C.

Simple statistics, including arith. mean, S.D., minimum, maximum, variance and coeff. of variation for the entire Fleet A is presented in Table exhaust-em.79 groups by individual MY in Tables 9.1-4A (App. C) and -4B. Table 9.1-4C shows arith. means by MY groups and by major manufacturers.

Table 9.1-5 then lists essential car data and FTP results, sorted by model year, manufacturer, CID and mileage. This sorted listing is useful for looking up a particular engine family (e.g. GM, 305 CID) and for comparing results of different model years.

Fleet A results are then plotted by MY: HC (FTP) results are shown in Fig. 9.1-1A and - 1B, CO (FTP) in Fig. 9.1-2A and -2B, NO_x in Fig. 9.1-3, fuel consumption FC in Fig. 9.1-4, CO-Idle in Fig. 9.1- 5 and CO-Fast Idle in Fig. 9.1-6. Specifically, Fig. 9.1-1A and -2A are useful in spotting out-liers (see Section 10.2 on Excessive Emitters).

In Figures 9.1-7A through -12, emissions are plotted against each other: HC (FTP) vs. CO (FTP) in Fig. 9.1-7A and -7B, HC (FTP) vs. CO-Idle in Fig. 9.1-8A and -8B, CO (FTP) vs. CO-Idle in Fig. 9.1-9, CO-Fast Idle vs. CO-Idle in Fig. 9.1-10, HC (FTP) vs. CO-Fast Idle in Fig. 9.1-11 and CO (FTP) vs. CO-Fast Idle in Fig. 9.1-12. In Fig. 9.1-13 the Fuel Consumption (FC) is plotted vs. CID.

Further evaluation of Fleet A is then done in two MY subgroups:
(a) newer cars, i.e. 1975-1984 MY (75/84 MY), total 248 cars, and
(b) older cars, i.e. pre-1975 MY (62/74 MY), consisting of the remaining 47 cars. Simple statistics (of numerical variables only) for these two MY subgroups are shown in Table 9.1-6 and 9.1-7. Accordingly, two more sets of plots are shown: Fig. 9.1-14A through -19 for the 75/84 MY group and Fig. 9.1-20A through -25 for the 62/74 MY group.

Table 9.1-4B

Fleet A (WOS 295) by MY: Arithmetic Means

Model Year	N (Cars)	Mileage (10^3 miles)	EPA Urban Cycle in G/Mile HC	CO	NO_x	Fuel Consump. L/100km	CO Idle % v.	CO Fast Idle % v.
1	2	3	4	5	6	7	8	9
1984	9	5.2	1.3	10.0	2.2	11.7	.4	.4
1983	20	10.4	1.0	10.6	2.7	12.4	.3	.2
1982	25	13.0	1.3	16.5	2.2	11.5	.7	.7
1981	25	13.6	1.1	16.7	2.6	12.2	1.0	.4
1980	30	25.1	2.2	26.9	2.3	13.4	1.2	.3
1979	34	35.3	2.0	24.5	2.8	13.5	1.0	.5
1978	36	48.0	3.1	42.8	2.8	14.0	2.6	.8
1977	30	59.1	3.0	36.2	3.1	15.1	2.3	.6
1976	21	68.3	3.0	47.6	2.8	16.4	3.0	.9
1975	18	72.8	3.3	50.3	3.5	17.4	3.0	1.0
1974	13	73.7	6.5	37.6	3.9	15.4	2.9	1.2
1973	9	73.6	3.5	74.7	3.7	16.0	2.8	1.6
1972	7	98.6	4.5	57.4	2.9	17.2	3.4	1.0
1971	7	117.1	9.2	57.8	3.6	16.7	2.2	1.8
1970	4	146.3	4.7	70.5	3.6	16.0	4.8	1.9
1969	1	52.0	5.8	74.4	3.7	17.3	2.6	1.5
1968	3	120.0	22.9	91.3	2.7	17.2	5.7	2.9
62 - 67	3	136.7	5.4	94.7	4.2	16.6	5.5	3.9
Mean	295	46.3	3.0	34.5	2.9	14.2	1.9	.8

Note: Based on Table 9.1-4A (Attach. C18-C37).

Table 9.1-4C

WOS 295 Arithmetic Means by MY Groups and Major Manufacturers

Model Year Group	MAN	N (Cars)	CID	Mileage (10^3 miles)	EPA Urban Cycle in G/Mile			Fuel Consump. L/100km	CO Idle % v.	CO Fast Idle % v.
					HC	CO	NO_x			
1	2	3	4	5	6	7	8	9	10	11
1970-74	AM	1	232	78	33.47	44.44	4.07	15.96	4.10	.35
	CH	8	293	94	4.11	72.17	4.26	16.72	4.32	1.51
	FO	5	321	106	5.55	43.33	4.21	18.74	3.38	1.20
	GM	19	324	94	5.32	58.84	3.33	17.32	2.72	1.12
1975-79	AM	6	236	58	1.99	28.28	3.28	14.53	1.15	.42
	CH	33	273	56	3.29	43.54	3.58	15.62	2.63	.74
	FO	24	263	56	2.63	36.36	2.78	15.52	2.09	.45
	GM	58	304	54	2.63	38.49	2.90	15.90	2.13	.59
1980-84	AM	3	222	24	.81	8.86	1.80	13.42	.70	.05
	CH	13	199	15	2.14	36.40	2.59	12.74	1.47	.64
	FO	21	188	15	2.39	29.63	1.59	12.93	.55	.47
	GM	55	230	15	.98	10.72	2.70	13.17	.47	.18

9.2 Fleet B: Ontario Sample - 200

As mentioned earlier, Fleet B is a subset of Fleet A. It consists of 197 cars of the 1962-1982 MY that closely match Target List 200. (Note: Instead of 6, only 3 testworthy cars were found in the 1962 - 67 MY category; i.e. cars # 290, 295 and 301. To complete OS 200 these 3 cars were represented twice, by clones # 9290, 9295 and 9301).

Table 9.2-1A (in App. D) shows how individual cars in OS 200 meet requirements of Target List 200 and indicates all deviations and substitutions. (Columns 1-6 specify the desired target car, columns 7-9 show the actual test car in OS 200. Nature of deviations and reasons for them are given in col. 10). It is like confronting theory (i.e. target car) with practice (i.e. test car). Results of OS 200 are then listed (by MY, MANUF, etc.) in Table 9.2-1B. (Note: Results of individual phases of test, i.e. Bags #1 - #5, should be looked up by test car # in Table 9.1 - 1B above). Fleet B characteristics by different variables are shown in Table 9.2-2A.

Table 9.2-2A

Fleet B - Characteristics

MY	62-67	68-70	71-74	75-79	80-82	83-84
%	3.0	3.0	14.5	46.0	33.5	0
MANUF	AM	CH	FO	GM	OTHER	
%	3.0	19.0	18.0	44.0	16.0	
CID	51-140	141-250	251-360	361-470	-	
%	26.0	25.0	46.0	3.0		
CYLIN	4	6	8	-	-	
%	29.0	23.0	48.0			
MILEAGE (000's)	0-10	11-20	21-40	41-60	61-100	101-200
%	13.5	12.5	25.5	14.0	23.0	11.5
INERTIA (000's)	2-3	3-4	4-5	5-6	-	
%	33.0	45.0	21.0	1.0		
OWNER	Private	Dealer	Rental	Gov't	-	-
%	87.0	5.5	5.5	2.0		
EM. SYSTEM	MOD	AIR	FUEL INJ	CAT	CAT+AIR	NONE
%	26.0	11.5	2.0	32.5	25.0	3.0
SPECIF	US	CAN	LABEL	N/A	-	-
%	36.5	22.0	20.0	21.5	-	-

Note: More detailed characteristics by MY including compliance with CANADA and ONTARIO standards are shown in Table 9.2-2B (App. D).

Table 9.2-4B

Fleet B (OS 200) by MY: Arithmetic Means

Model Year	N (Cars)	Mileage (10^3 miles)	EPA Urban Cycle in G/Mile HC	 CO	 NO_x	Fuel Consump. L/100km	CO Idle % v.	CO Fast Idle % v.
1	2	3	4	5	6	7	8	9
1982	19	11.2	1.3	16.6	2.2	11.5	.7	.7
1981	23	14.0	1.1	16.4	2.7	12.3	1.1	.4
1980	25	27.9	2.3	25.7	2.1	13.0	1.3	.3
1979	22	33.4	1.9	24.3	3.0	13.4	1.1	.5
1978	22	42.4	3.2	44.8	2.6	13.6	2.2	.8
1977	18	54.0	3.0	38.2	2.8	14.6	2.4	.8
1976	16	65.1	3.2	53.4	2.9	15.6	3.6	1.0
1975	14	77.9	3.3	51.3	3.6	16.9	3.4	1.2
1974	11	76.8	7.4	41.0	3.9	16.1	3.3	1.4
1973	8	78.3	3.7	80.0	3.6	16.4	3.1	1.8
1972	6	93.5	4.5	53.1	3.0	17.2	3.2	1.1
1971	4	121.3	13.0	69.9	3.4	17.7	3.0	3.0
1970	3	131.0	4.6	61.4	3.4	16.6	4.1	1.3
1969	1	52.0	5.8	74.4	3.7	17.3	2.6	1.5
1968	2	145.5	32.9	130.7	1.1	16.8	8.4	4.2
62-67	6	136.7	5.4	94.7	4.2	16.6	5.5	3.9
Mean	200	50.4	3.4	39.5	2.9	14.3	2.2	1.0

Note: Based on Table 9.2-4A (Attach. D15-D19).

Table 9.2-2C then compares (by MY, MANUF) the actual characteristics of OS 200 to requirements of Target List 200. Simple statistics for the whole Fleet B is shown in Table 9.2-3, statistics for individual MY groups (in abbreviated form) is presented in Table 9.2-4A (App. D) and -4B. Results of Fleet B are then plotted by MY in Fig. 9.2-1 through -6. Further plots are shown in Fig. 9.2-7 through -12.

9.3 Fleet C - High Mileage Government Cars

There are 52 high-mileage police and government cars of the 1974-79 MY in Fleet C. These were tested in the very first phase of the test program mainly to establish test routines and to investigate FTP vs. MFTP correlations. Complete results of Fleet C are listed in Table 9.3-1A and 1B (App. E).

Table 9.3-1C

Fleet C - Brief Characteristics

MY	62-67	68-70	71-74	75-79	80-82	83-84
%	0	0	3.8	96.2	0	0
MANUF	AM	CH	FO	GM	OTHER	
%	0	44.2	25.0	30.8	0	
CID	51-140	141-250	251-360	361-470	-	
%	0	7.7	76.9	15.4		
CYLIN	4	6	8	-	-	
%	0	7.7	92.3			
MILEAGE (000's)	0-10	11-20	21-40	41-60	61-100	101-200
%	0	1.9	3.8	5.8	80.8	7.7

Table 9.3-2B

Fleet C by Model Year: Arithmetic Means

Model Year	N (Cars)	Mileage (10^3 miles)	EPA Urban Cycle in G/Mile HC	EPA Urban Cycle in G/Mile CO	NO_x	Fuel Consump. L/100km	CO Idle % v.	CO Fast Idle % v.
1	2	3	4	5	6	7	8	9
1979	8	93	3.9	51.2	1.2	17.4	1.3	1.0
1978	14	80	3.8	46.2	2.3	18.8	1.6	.3
1977	17	81	3.3	47.2	2.8	17.2	2.1	.4
1976	8	74	2.7	47.1	2.0	20.6	1.1	.4
1975	3	75	2.9	37.9	2.0	22.6	1.4	1.0
1974	2	57	1.7	21.4	2.9	20.1	.3	.1
Mean	52	80	3.3	46.0	2.3	18.6	1.6	.5

Note: Data extracted from L10, job #22.

Brief characteristics of Fleet C, in Table 9.3-1C, and simple statistics, in Table 9.3-2A, indicate heavy slant towards large V8 engines with high mileages (avg. 350 CID with 80,400 miles). Table 9.3-2B presents arithmetic means by MY, and Table 9.3-3 lists individual FTP results sorted by model year, manufacturer, CID and mileage.

Only one plot is attached, Fig. 9.3-1, showing HC (FTP) vs. CO (FTP). It shows all cars except car #8, which was excessive in HC (18.5 gpm) and CO (125.3 gpm), and therefore out of ranges. Table 9.3-4 is a matrix showing simple correlation coefficients between individual variables.

9.4 Other Test Data (Fleet D and Retests)

Fleet D consists of 11 cars that were special in one way or another: 2 cars (#225,226) were powered by propane, 3 cars (#1,3,4) were Ontario government cars tested during the first few weeks of the test program to acquire practice and to investigate repeatability of the hot-start (MFTP) procedure, 6 cars (# 23, 216, 227, 250, 321, 334) were tested hot-start only (after the cold-start test had to be aborted due to test equipment or car failure). Results of Fleet D are shown in Table 9.4-1, parts (a) to (c). In part (d) are retests of 5 cars from Fleet A (# 157, 224, 245, 266, 342). Table 9.4- 2 compares the propane-powered cars (#225,226) with 4 gasoline- powered cars of the same make, CID and of the same or similar MY (cars # 195, 316, 340, 343). Table 9.4-3 then compares arithm. means of these two groups.

Table 9.4-3

Comparison of Propane to Gasoline Powered Cars (FORD, 140 CID) - Arith. Means

					EPA Urban Test				CO	CO
Group	N (Cars)	Dyno Inertia (Lbs)	MY	Mileage (Miles)	HC g/mi	CO g/mi	NO_x g/mi	Fuel Consum. (L/100 km)	Idle % v.	Fast Idle % v.
Prop.	2	3500	82	9,500	1.64	7.25	7.86	15.13	1.00	.15
Gasol.	4	2938	82/84	14,750	1.06	13.82	1.48	11.67	.29	.05

Table 9.4-1 Fleet D (and Retests of Fleet A)

TEST CAR	SUBTEST	OWNER	INERTIA	SPECIF	MANUF	CAR MAKE-MODEL	MODELYR	TRANSM	LITRES	CID	ENGTYPE	CARBVEN	MILEAGE	MAIN EMISSION CONTROL SYSTEM	FTP (EPA URBAN)			FUEL CONS.	CO	CO	CANADA	ONTARIO
															HC g/mi	CO g/mi	NO_x g/mi	L/100 km	IDLE % v.	FAST IDLE % v.		
(a) Propane cars (2), FTP + TB																						
225	0	C	350	L	30	MERC-COUGAR	82	A3	2.3	140	L4	0	7	MOD+PRP	1.56	11.75	7.61	15.83	1.70	.10	4	0
226	0	C	350	L	30	MERC-COUGAR	82	A3	2.3	140	L4	0	12	MOD+PRP	1.72	2.74	8.10	14.43	.30	.20	4	0
(b) Practice tests (3 cars), FTP + TB																						
1	0	V	550		20	PLYM-SUBURB	74	A3	5.9	360	V8	2	69	MOD	5.52	110.60	5.51	26.91	1.20	2.00	7	4
3	0	V	550		20	PLYM-SUBURB	75	A3	5.9	360	V8	2	68	MOD	4.12	72.36	6.39	20.44	1.85	.35	7	0
4	0	B	450		40	CHEV-IMPALA	79	A3	5.0	305	V8	2	6	CAT	.54	7.45	3.50	15.12	.05	.05	4	0
(c) Hot-start tests (6 cars), TB only																						
23	8	B	450		40	CADI-FLETW	79	A2	7.0	425	V8	4	49	CAT					.05	0.05	–	1
216	8	R	300	C	40	CHEV-CITATI	82	A3	2.5	151	L4	2	3	CAT+AIR					.05	1.80	–	4
227	8	P	225	C	75	VW-RABBIT	79	M5	1.5	89	L4	0	44	FUEL INJ					1.80	1.00	–	0
250	8	R	300	C	40	BUIC-CENTUR	82	A3	2.8	173	V6	2	14	CAT					4.20	.10	–	2
321	8	V	263	C	20	PLYM-RELIAN	83	A3	2.6	156	L4	2	4	MOD					.10	1.40	–	4
334	8	R	450	U	30	LINC-TOWNCA	83	A3	5.0	302	V8	2	12	CAT+AIR					.05	.05	–	0
(d) Retests of 5 cars from Fleet A, FTP + TB																						
157	1	P	350	C	40	PONT-GLEMAN	79	A3	5.0	305	V8	4	26	CAT	.84	9.98	2.55	14.72	.01	.01	0	0
224	0	P	450	U	40	OLDS-CUTLAS	74	A3	5.7	350	V8	4	112	MOD	7.21	52.52	N/A	17.89	3.60	.20	3	3
245	1	P	550	U	40	CHEV-KINGSW	71	A3	5.7	350	V8	2	163	MOD-DEF	36.65	136.77	2.28	23.12	5.40	3.00	3	7
266	1	P	500	U	40	PONT-LAUREN	72	A3	5.7	350	V8	2	1.09	MOD-DEF	3.00	45.79	4.34	20.05	3.20	1.40	6	6
342	1	P	350	U	40	CHEV-NOVA	71	A3	4.1	250	L6	1	153	MOD	2.76	33.96	2.19	15.31	.60	.10	0	0

Not shown are data of Fleet E. It consists of 16 cars, the results of which were discarded due to suspected CVS or calibration problems (cars # 118, 119, 137-147, 155, 156, 337).

Tables 9.4-4 and -5 show results of 5 private cars that, as a matter of coincidence, necessity or interest, were retested after a period of 1½ to 5 months. Original results (code 0), if complete, were used to represent these cars in WOS 295. Only car #224 was represented by a retest (code 1), due to missing NO_x data. According to car owners, there was no maintenance or adjustment in the interim. Car #245, retested after over 5 months, happened to be an excessive emitter (EE). Its CO emissions, both in FTP and in Idles, varied greatly and some adjustments and/or spontaneous change in its emission characteristics were suspected.

Table 9.4-4

Retests of 5 private cars (from Fleet A)

			Engine			EPA Urban Test Results			Fuel	CO	CO	
Test Car	Sub-Test	Test Date	MY	CID	Mileage 10^3	HC g/mi	CO g/mi	NO_x g/mi	Consum. (L/100 km)	Idle % v.	Fast Idle % v.	
157	0	Sept 17/81	79	305	26	.81	10.11	2.88	14.76	.10	.60	*
	1	Oct 30/81			26	.84	9.98	2.55	14.72	.01	.01	
224	0	Aug 12/82	74	350	112	7.21	52.52	N/A	17.49	3.60	.20	(1)
	1	Sept 23/82			113	8.36	69.86	4.81	18.10	4.40	.35	*
245	0	Oct 29/82	71	350	160	32.94	76.11	3.61	21.94	2.60	7.00	*
	1	Apr 7/83			163	36.65	136.77	2.28	23.12	5.40	3.00	(2)
266	0	Jan 21/83	72	350	107	2.81	48.01	3.23	20.16	3.80	1.20	*
	1	Apr 8/83			109	3.00	45.79	4.34	20.05	3.20	1.40	
342	0	Feb 2/84	71	250	152	2.68	32.29	2.47	15.17	.20	.10	*
	1	Mar 23/84			153	2.76	33.96	2.19	15.31	.60	.10	

Notes: * This test was included in WOS 295.
(1) NO_x data missing
(2) Retest after more than 5 months

Table 9.4-5

Retests: Changes in Emissions, % rel.

Car #	Change in emissions (%)		
	HC	CO	NO_x
157	+ 3.7	- 1.3	-11.5
224	+15.9	+33.0	N/A
245	+11.3	+79.7	-36.8
266	+ 6.8	- 4.6	+34.4
342	+ 3.0	+ 5.2	-11.3

$$\% \text{ rel.} = \frac{(\text{Retest} - \text{Base}) \times 100}{\text{Base}}$$

10.0 DISCUSSION OF TEST RESULTS

10.1 Fleet A : WOS 295

Sample characteristics (in Table 9.1-2) indicate a fair mixture of makes and engine sizes. The inertia weights demonstrate the expected tendency towards lighter vehicles. Owner data show a large presence of rental vehicles in 1982-84 MY (resulting from last minute substitutions for other scheduled, but not delivered test cars): 40% in 82 MY and almost 80% in 83/84 MY. The use of rental cars in 83/84 MY resulted in a bias towards GM and Ford products and in a lack of any Chrysler products (These biases should be considered when analyzing test results for 82-84 MY).

Arithmetic means (mileage, emissions, FC in Table 9.1-4B), follow a logical trend, i.e. increase with older models. There are some "bumps", such as HC in 74, 71 and 68 MY, CO in 73 MY etc., which can be explained either by a low number of cars in MY sample, or by unusually high presence of excessive emitters (see Table 10.2-2).

A comparison of the 4 major manufacturers (Table 9.1-4C), reveals slightly higher HC and CO emissions of Chrysler 75/79 MY cars, in FTP as well as in Idles. The 80/84 MY group, although to some degree affected by rental car bias discussed above, indicates the same.

Plots by MY (Figures 9.1-1A and -2A) indicate the presence of a number of excessive emitters. These have been identified and dealt with separately in Section 10.2 below.

Visual examination of plots (= scattergrams in Figure 9.1-7A to - 13) indicates possible relationship (relatability) between plotted variables. Sample correlation coefficients $\underline{r}$ were calculated for the whole WOS 295, see Table 10.1-1.

Correlation coefficients r are rated using the following rating system (L51):

	Rating	Absolute Value of Correl. Coeff. r
E	Excellent	0.9 - 1.0
G	Good	0.7 - 0.9
F	Fair	0.6 - 0.7
P	Poor	< 0.6, but correlated at 95% confid. level
U	Unacceptable	< 0.6, and uncorrelated at 95% confid. level

Note: Negative **r** indicates inverse relationship between variables.

There is a good correlation between FC and INERTIA (0.88), also between FC and CID (0.89). This is not unexpected, as inertia reflects weight of vehicle, and CID indirectly too (heavy vehicles have large engines). Also, correlations between weighted EPA results and individual phases of FTP (i.e. EPCOLD, EPSTAB and EPHOT) are excellent or at least good, due to built-in auto-correlation.

Correlations between weighted EPA results and phases of the MFTP (two-bag test, i.e., TBSTAB and TBHOT) are very high, with r from 0.84 to 0.99. This indicates a good relatability between the MFTP and the FTP.

Correlations among other variables are then below 0.6, i.e. poor or unacceptable. All correlations involving MODELYR are negative and poor (r from -0.20 to -0.52), all correlations involving MILEAGE are positive and poor (r from 0.20 to 0.54); both effects are logical and predictable.

In Tables 10.1 - 2 and -3, WOS 295 is split into 2 groups by MY: 75/84 MY group with 248 cars and 62/74 MY group with 47 cars. (Note: 1975 is a landmark year due to introduction of much stricter emission standards, of catalytic converters, and of a new test procedure FTP-75, see Table 2.2-1). Correlation coefficient for both MY groups follow roughly the same patterns as for the entire WOS 295.

Table 10.1 - 1

Simple Correlation Coefficients
Fleet A (WOS 295), 1962-84 MY (295 cars)

	TEST/CAR PARAMETERS				EPA URBAN TEST RESULTS			
VARIABLE	INERTIA	MODELYR	CID	MILEAGE	HCEP-WEIG	COEP-WEIG	NOEP-WEIG	FCEP-WEIG
1	2	3	4	5	6	7	8	9
HCEPWEIG	.14	-.40	.10	.42	1.00	.53	*	.28
COEPWEIG	.20	-.52	.23	.54	.53	1.00	*	.47
NOEPWEIG	.30	-.28	.25	.28	*	*	1.00	.20
FCEPWEIG	.88	-.44	.89	.46	.28	.47	.20	1.00
COIDLE	*	-.46	*	.52	.34	.62	.13	.15
COFASTID	-.18	-.42	-.19	.38	.38	.42	*	*
HCEPCOLD	.21	-.42	.17	.44	.94	.52	*	.34
EPSTAB	.11	-.37	*	.38	.99	.49	*	.24
EPHOT	.15	-.41	.12	.44	.95	.57	*	.30
TBHOT	.16	-.42	.12	.46	**.92**	.56	*	.31
TBSTAB	.12	-.39	*	.41	**.99**	.53	*	.26
COEPCOLD	.26	-.51	.27	.49	.39	.82	*	.48
EPSTAB	.17	-.49	.20	.53	.51	.98	*	.43
EPHOT	.17	-.46	.18	.48	.55	.96	*	.42
TBHOT	.17	-.45	.16	.46	.71	**.84**	-.11	.38
TBSTAB	.15	-.48	.16	.50	.71	**.86**	*	.37
NOEPCOLD	.26	-.20	.23	.20	*	*	.87	.14
EPSTAB	.27	-.24	.21	.23	*	*	.95	.17
EPHOT	.30	-.34	.27	.33	*	*	.96	.24
TBHOT	.33	-.33	.30	.35	*	*	**.93**	.25
TBSTAB	.30	-.27	.25	.28	*	*	**.92**	.21
FCEPCOLD	.87	-.44	.88	.45	.23	.43	.21	.97
EPSTAB	.86	-.43	.87	.46	.29	.48	.20	.99
EPHOT	.89	-.42	.88	.44	.27	.44	.19	.99
TBHOT	.88	-.45	.87	.48	.35	.43	.17	**.97**
TBSTAB	.82	-.47	.82	.49	.42	.48	.18	**.94**

* absolute value of r is below 0.10.

Note: Correlations with an absolute value of r > 0.117 are statistically significant at the 95% confidence level.

Table 10.1 - 2

Simple Correlation Coefficients
Fleet A (WOS 295), 1975-84 MY (248 cars)

	TEST/CAR PARAMETERS				EPA URBAN TEST RESULTS			
VARIABLE	INERTIA	MODELYR	CID	MILEAGE	HCEP-WEIG	COEP-WEIG	NOEP-WEIG	FCEP-WEIG
1	2	3	4	5	6	7	8	9
HCEPWEIG	.17	-.37	.18	.48	1.00	.87	*	.38
COEPWEIG	.17	-.43	.19	.48	.87	1.00	*	.41
NOEPWEIG	.29	-.22	.23	.26	*	*	1.00	.19
FCEPWEIG	.89	-.46	.89	.44	.38	.41	.19	1.00
COIDLE	*	-.41	*	.49	.44	.60	*	*
COFASTID	-.25	-.20	-.23	.20	.31	.38	*	-.14
HCEPCOLD	.29	-.39	.29	.46	.85	.71	*	.44
EPSTAB	.11	-.33	.13	.45	.99	.87	*	.33
EPHOT	.15	-.35	.15	.45	.97	.85	*	.35
TBHOT	.15	-.37	.16	.47	**.90**	.81	*	.34
TBSTAB	*	-.36	.10	.46	**.95**	.88	*	.31
COEPCOLD	.24	-.44	.25	.40	.71	.81	*	.44
EPSTAB	.14	-.41	.16	.48	.85	.98	*	.37
EPHOT	.15	-.35	.16	.40	.86	.96	*	.38
TBHOT	.16	-.34	.17	.41	.80	**.90**	-.11	.38
TBSTAB	.13	-.41	.16	.48	.80	**.95**	*	.36
NOEPCOLD	.26	-.10	.22	.16	*	*	.85	.14
EPSTAB	.26	-.20	.19	.22	*	*	.95	.16
EPHOT	.29	-.28	.24	.33	.10	*	.96	.22
TBHOT	.32	-.25	.27	.32	*	*	**.94**	.23
TBSTAB	.28	-.22	.22	.27	*	*	**.93**	.20
FCEPCOLD	.89	-.47	.89	.44	.34	.38	.19	.97
EPSTAB	.88	-.44	.88	.44	.39	.42	.19	.99
EPHOT	.89	-.45	.89	.44	.37	.40	.16	.99
TBHOT	.89	-.44	.89	.44	.34	.37	.16	**.98**
TBSTAB	.84	-.44	.85	.44	.37	.41	.18	**.97**

* absolute value of r is below 0.10.

Note: Correlations with an absolute value of r > 0.123 are statistically significant at the 95% confidence level.

Table 10.1 - 3

Simple Correlation Coefficients
Fleet A (WOS 295), 1962-74 MY (47 cars)

	TEST/CAR PARAMETERS				EPA URBAN TEST RESULTS			
VARIABLE	INERTIA	MODELYR	CID	MILEAGE	HCEP-WEIG	COEP-WEIG	NOEP-WEIG	FCEP-WEIG
1	2	3	4	5	6	7	8	9
HCEPWEIG	.11	-.16	*	.21	1.00	.31	-.30	.16
COEPWEIG	.19	-.33	.17	.33	.31	1.00	-.31	.44
NOEPWEIG	.26	*	.19	-.11	-.30	-.31	1.00	*
FCEPWEIG	.86	*	.86	.22	.16	.44	*	1.00
COIDLE	*	-.32	*	.33	.22	.48	*	*
COFASTID	-.24	-.42	-.41	.30	.32	.26	.14	-.25
HCEPCOLD	.13	-.14	*	.21	.96	.31	-.25	.20
EPSTAB	*	-.18	*	.20	.99	.30	-.32	.13
EPHOT	.15	-.11	*	.21	.95	.27	-.22	.18
TBHOT	.15	-.12	*	.24	**.91**	.30	-.22	.19
TBSTAB	.12	-.15	*	.22	**.99**	.28	-.28	.16
COEPCOLD	.23	-.34	.22	.33	.12	.78	-.28	.47
EPSTAB	.16	-.25	.16	.28	.31	.96	-.26	.38
EPHOT	.13	-.39	*	.33	.41	.93	-.34	.33
TBHOT	*	-.38	*	.28	.72	**.71**	-.46	.21
TBSTAB	*	-.29	*	.24	.71	**.68**	-.40	.19
NOEPCOLD	.15	.15	.12	-.14	-.32	-.39	.92	-.12
EPSTAB	.30	*	.18	*	-.23	-.28	.94	*
EPHOT	.25	.17	.22	-.17	-.31	-.24	.94	*
TBHOT	.24	.22	.22	*	-.33	-.39	**.89**	*
TBSTAB	.28	*	.17	*	-.16	-.35	**.84**	*
FCEPCOLD	.83	*	.84	.20	*	.37	*	.96
EPSTAB	.83	*	.85	.22	.20	.47	*	.99
EPHOT	.88	*	.86	.23	.17	.40	*	.99
TBHOT	.79	*	.73	.29	.45	.39	-.20	**.90**
TBSTAB	.71	*	.67	.24	.54	.39	-.16	**.80**

* absolute value of r is below 0.10.

Note: Correlations with an absolute value of r >0.288 are statistically significant at the 95% confidence level.

Of main interest are correlations between EPA weighted results and phases of MFTP, see Table 10.1-4. Values of r for the 75/84 MY group are generally higher (except for HC). Also, in the 75/84 MY, there is a higher cross-correlation between HCEPWEIG and COEPWEIG (r = 0.53 for 62/84 MY, r = 0.87 for 75/84 MY).

One finding is common to WOS 295 and to its subgroups by MY: NO_X are not cross-correlated to HC or CO (or CO in Idle or Fast Idle).

Table 10.1-4

Simple Correlation Coefficients between FTP-75 Results (EPWEIG) and the Phases of MFTP-75 (TBHOT or TBSTAB), Fleet A (WOS 295) and Fleet B (OS 200)

SAMPLE	MY Group	N (Cars)	HC		CO		NO		FC	
			TB HOT	TB STAB	TB HOT	TB STAB	TB HOT	TB STAB	TB HOT	TB STAB
WOS 295	62/84	295	.92	.99	.84	.86	.93	.92	.97	.94
WOS 295	62/74	47	.91	.99	.71	.68	.89	.84	.90	.80
	75/84	248	.90	.95	.90	.95	.94	.93	.98	.97
OS 200	62/82	200	.92	.99	.84	.84	.92	.93	.96	.93

Note: All correlations are statistically significant at the 95% confidence level.

More work was done on multiple linear regression analysis, i.e. to evaluate relationship between a dependent variable (e.g. HCEPWEIG) and two or more independent variables (e.g. HCTBHOT, HCTBSTAB, INERTIA, CID, MILEAGE, MODELYR). Coefficient of determination R^2 (R-SQUARE) was used as criterion. It shows the amount of variation in the dependent variable accounted for by the model. The idea of Table 10.1-5 is to find whether inclusion of a third, fourth, etc. variable in addition to TBHOT and TBSTAB (and intercept) does improve R-SQUARE and by how much. Again, WOS

295 is split into two MY groups. Generally, the inclusion of a third variable does not improve R^2 significantly, except in 62/74 MY group, where MILEAGE improved R^2 for CO, and CID improved R^2 for FC. These two variables (MILEAGE, CID) might be considered for inclusion in future models dealing with 62/74 MY cars and based on phases of MFTP (i.e. TBHOT and TBSTAB).

Table 10.1 - 5

R-SQUARE of Multiple Linear Regressions

Fleet A (WOS 295) by MY Groups (1)

Model Year MY independent	N (Cars)	Y (Dependent) EPWEIG	R-SQUARE after inclusion of independent variables into model (2)						Improvement in R^2 due to inclusion of the best variable
			TWO (i.e. TBHOT & third TBSTAB) (2)	THREE (i.e. TBHOT, TBSTAB and one of these)				ALL 6 (i.e.TBHOT, TBSTAB, INERTIA, CID, MY, MILEAGE)	
				INERT (3)	CID (3)	MILE (3)	MY (3)		
a	b	c	d	e	f	g	h	i	j
75/84	244	HC	.911	**.916**	.915	.912	.912	.916	.005
	246	CO	.914	**.916**	.915	.915	**.916**	.916	.002
	246	NO	.927	.927	.927	**.928**	.927	.929	.001
	246	FC	.975	.977	**.977**	.975	.976	.977	.002
62/74	44	HC	.991	.991	.991	.991	**.991**	.991	.000
	45	CO	.497	.503	.518	**.522**	.501	.554	.025
	45	NO	.827	.830	**.833**	.829	.830	.843	.006
	45	FC	.824	.853	**.888**	.824	.827	.891	.064

Notes:

(1) R^2 (R-SQUARE), also called coefficient of determination, shows the amount of variation in the dependent variable (e.g., HCEPWEIG) accounted for by the model.

(2) All models include TBHOT, TBSTAB and intercept.

(3) Best third variable is printed **heavy**.

In Table 10.1-6 a similar investigation (into impact of additional variables on R^2) is done by individual model years. For HC the most popular third variable seems to be CID, for CO and NO it is MILEAGE, for FC it is INERTIA. Achieved improvements in R^2 (see col. i) are far from spectacular and the need for a model with additional variables (on top of TBHOT, TBSTAB and intercept) is debatable.

Table 10.1-7 then establishes individual model parameters for multiple l regressions based on a simple 2-variable model:

$$Y = a\ X_1 + b\ X_2 + i$$

where X_1 = TBHOT, X_2 = TBSTAB and i = intercept.

Amounts of variation accounted for by these models are: 73%- 99% for HC, 78%-99% for CO, 89%-97% for NO, and 93%-99% for FC (depending on model year MY).

Table 10.1-8A provides similar model parameters for the two subgroups: 75/84 MY and 62/74 MY. The model may be expanded by inclusion of a third variable, X_3 = MODELYR. Table also shows the 2-variable models, with and without intercept.

The usefulness of MFTP in estimating the population means (in lieu of FTP) is demonstrated in Table 10.1-8B. The multiple linear model (with TBHOT, TBSTAB and intercept) was verified using five cars from a different car sample. (Note: Cars # 505-509 were selected at random from the 1986 data base generated after the calculation of model parameters in Tables 10.1-7 and -8, above). Shown are FTP results (i.e. EPWEIG) and two predicted values based on MFTP. The latter were calculated using model parameters for the 75/84 MY group and for the respective model years.

For individual cars the predicted values differ from FTP by -32% rel. up to +73% rel. In the case of population means (5 cars) the differences are much smaller, from -0.3% to +4.3% rel.

Table 10.1 - 6

R-SQUARE of Multiple Linear Regressions
Fleet A (WOS 295) by MY (1)

Model Year MY	N (Cars)	Y (Dependent) EPWEIG	R-SQUARE after inclusion of independent variables into model (2)					Improvement in R_2 due to inclusion of the best third independent variable
			TWO (i.e. TBHOT & TBSTAB) (2)	THREE (i.e. TBHOT, TBSTAB and one of these)			ALL 6 (i.e.TBHOT, TBSTAB, INERTIA, CID, MY, MILEAGE)	
				INERT (3)	CID (3)	MILE (3)		
a	b	c	d	e	f	g	h	i
75	17	HC	.966	.967	.967	**.968**	.969	.002
76	21		.891	.903	**.910**	.898	.929	.019
77	30		.920	.920	.921	**.922**	.924	.002
78	36		.860	.880	**.883**	.877	.893	.023
79	34		.726	.729	.728	**.740**	.743	.014
80	30		.998	.999	**.999**	.998	.999	.001
81	25		.869	.879	**.880**	.869	.886	.011
82	24		.920	.931	**.933**	.929	.939	.013
83	20		.897	**.933**	.931	.903	.946	.036
84	9		.982	.983	.983	**.985**	.985	.003
75	17	CO	.953	.955	.954	**.957**	.962	.009
76	21		.869	.871	.869	**.874**	.889	.005
77	30		.783	.794	.791	**.801**	.805	.018
78	36		.947	.948	.948	**.960**	.960	.013
79	34		.879	.882	.880	**.886**	.893	.007
80	30		.991	.993	**.993**	.992	.994	.002
81	25		.804	**.806**	.804	.806	.816	.002
82	24		.913	**.921**	.918	.920	.932	.008
83	20		.906	.913	**.924**	.906	.943	.018
84	9		.944	.946	**.946**	.945	.946	.002
75	17	NO	.926	.927	.928	**.928**	.930	.002
76	21		.972	**.976**	.974	.972	.980	.004
77	30		.917	.920	**.924**	.919	.927	.007
78	36		.946	.947	.947	**.950**	.951	.004
79	34		.931	.944	**.944**	.933	.946	.013
80	30		.899	**.902**	.890	.901	.906	.003
81	25		.923	**.941**	.932	.923	.958	.018
82	24		.972	.972	.972	**.973**	.973	.001
83	18		.944	.944	.945	**.950**	.951	.006
84	9		.885	.921	.913	**.934**	.966	.049
75	17	FC	.977	**.983**	.978	.977	.984	.006
76	21		.986	.987	**.989**	.986	.990	.003
77	30		.986	**.987**	.986	.986	.987	.001
78	36		.985	**.987**	.987	.985	.988	.002
79	34		.986	.988	**.989**	.987	.990	.003
80	30		.968	.969	.968	**.969**	.970	.001
81	25		.926	**.956**	.947	.931	.958	.030
82	24		.975	**.977**	.975	.976	.979	.002
83	20		.997	**.998**	.998	.997	.998	.001
84	9		.989	.991	**.992**	.989	.992	.003

Notes: (1) R_2 (R-SQUARE), also called coefficient of determination, shows the amount of variation in the dependent variable (e.g. HCEPWEIG) accounted for by the model.

(2) All models include TBHOT, TBSTAB and intercept.

(3) Best third variable is printed **heavy**.

Table 10.1 - 7

Estimates of Model Parameters for Multiple Linear Regressions Fleet A (WOS 295), by Model Year

Model Year MY	N Cars)	Y (Dependent) EPWEIG	Coefficients (1) a (for X_1 = TBHOT)	b (for X_2 = TBSTAB)	i Intercept	R^2 (2)	Note
Col.1	2	3	4	5	6	7	8
75	17	HC	.868	.392	-.187	.966	(3)
76	21		-.110	.938	.616	.891	
77	30		.449	.575	.274	.920	
78	36		.256	.379	1.343	.860	
79	34		1.377	-.274	.197	.726	
80	30		.103	1.039	.135	.998	
81	25		.259	.687	.294	.869	
82	24		.324	.566	.332	.920	
83	18		.190	.682	.399	.897	
84	9		.680	.358	.065	.982	
75	17	CO	1.113	.180	2.740	.953	
76	21		-.289	.885	12.800	.869	
77	30		-.169	.848	10.437	.783	
78	36		.566	.371	9.111	.947	
79	34		.202	.608	10.112	.879	
80	30		.459	.655	2.813	.991	
81	25		.371	.594	4.037	.804	
82	24		.415	.459	3.821	.913	
83	18		.487	.633	2.286	.906	
84	9		.474	.369	-.231	.944	
75	17	NO	.194	.812	.341	.926	
76	21		.422	.507	.160	.972	
77	30		.549	.295	.228	.917	
78	36		.351	.542	.294	.946	
79	34		.314	.601	.348	.931	
80	30		.734	.250	-.086	.899	
81	25		.497	.422	.293	.923	
82	24		.494	.379	.237	.972	
83	18		.442	.445	.245	.944	
84	9		.364	.413	.682	.885	
75	17	FC	.716	.344	.108	.977	
76	21		.475	.572	-.093	.986	
77	30		.304	.659	.950	.986	
78	36		.572	.449	.394	.985	
79	34		.308	.696	.381	.986	
80	30		.393	.651	-.041	.968	
81	25		.934	.096	.839	.926	
82	24		.291	.727	.036	.975	
83	18		.676	.371	.057	.997	
84	9		.511	.443	.811	.989	

Notes:

(1) Multiple linear equation: $Y = aX_1 + bX_2 + i$

(2) R^2 (R-SQUARE) shows amount of variation in the dependent variable (eg., HCEPWEIG) accounted for by the model.

(3) Model for dependent variable HCEPWEIG (in 1975 MY) is e.g., HCEPWEIG = 0.868 (HCTBHOT) + 0.392 (HCTBSTAB) - 0.187. Similarly other models can be construed for other MY and for CO, NO and FC.

Table 10.1 - 8A

Estimates of Model Parameters for Multiple Linear Regressions Fleet A (WOS 295), by MY Group

				Coefficients (1)			
MY Group	N (Cars)	Y (Dependent) EPWEIG	a (for X_1= TBHOT)	b (for X_2= TBSTAB)	c (for X_3= MODELYR	i Intercept	R^2 Multiple Correl. Coeff. (2)
Col.1	2	3	4	5	6	7	8
	(A) 75 and newer MY						
75/84	244	HC	.311	.704	*	.302	.911
	246	CO	.272	.641	*	5.738	.914
	246	NO	.423	.463	*	.302	.927
	246	FC	.721	.331	*	.196	.975
75/84	244	HC	.426	.681	*	*	.954
	246	CO	.449	.599	*	*	.948
	246	NO	.482	.485	*	*	.985
	246	FC	.737	.330	*	*	.999
75/84	244	HC	.307	.702	-.010	1.136	.912
	246	CO	.283	.619	-.496	45.350	.916
	246	NO	.428	.463	-.011	-.586	.927
	246	FC	.718	.328	-.020	1.838	.976
	(B) 74 and older MY						
62/74	44	HC	-.271	1.151	*	.771	.991
	45	CO	.613	-.024	*	35.136	.497
	45	NO	.442	.332	*	.565	.827
	45	FC	1.284	-.219	*	1.217	.824
62/74	44	HC	-.153	1.108	*	*	.992
	45	CO	1.262	-.201	*	*	.766
	45	NO	.537	.350	*	*	.977
	45	FC	1.402	-.253	*	*	.993
62/74	44	HC	-.268	1.147	-.053	4.570	.991
	45	CO	.541	.010	-.947	104.013	.501
	45	NO	.462	.314	-.028	2.508	.830
	45	FC	1.281	-.212	.082	-4.726	.827

Notes: (1) Multiple linear equation: $Y = aX_1 + bX_2 + cX_3 + i$.

(2) R^2 (R-SQUARE) shows variation in the dependent variable (e.g. HCEPWEIG) accounted for by the model.

* Not used in this model.

Table 10.1-8B

Verification on Multiple Linear Model

Test Car #	MY	FTP or Predicted by Model	HC	CO	NO_x	FC	Note
			Test Results (g/mi or L/100 km)				
505	76	FTP	2.16	60.84	2.15	18.80	
		Model (group)	2.49	71.31	2.10	19.12	
		Model (indiv.)	2.47	64.74	2.03	19.19	
506	78	FTP	2.65	23.63	7.31	12.14	
		Model (group)	2.68	22.93	6.72	12.32	
		Model (indiv.)	2.82	24.33	6.65	12.25	
507	83	FTP	1.19	16.73	1.73	9.84	
		Model (group)	1.08	13.22	3.00	9.70	
		Model (indiv.)	1.06	11.42	2.98	9.56	
508	77	FTP	.54	11.45	1.64	10.22	
		Model (group)	.78	10.92	1.39	10.41	
		Model (indiv.)	.77	10.14	1.40	9.82	
509	77	FTP	2.87	30.67	3.83	14.69	
		Model (group)	2.63	31.09	3.76	14.82	
		Model (indiv.)	2.48	37.51	3.82	14.69	
Means of 5 cars		FTP	1.88	28.66	3.33	13.14	
		Model (group)	1.93	29.89	3.39	13.27	
		Model (indiv.)	1.92	29.63	3.38	13.10	
		Difference from FTP (% rel.)					
Means of 5 cars		Model (group)	+2.7	+4.3	+1.9	+1.0	
		Model (indiv.)	+2.0	+3.4	+1.3	-0.3	

Notes:

FTP	EPWEIG results
Model(group)	predicted using TBHOT, TBSTAB and model parameters for 75/84 MY group (from Table 10.1-8).
Model(indiv.)	predicted using TBHOT, TBSTAB and model parameters for individual MY (from Table 10.1-7)

10.1.1 Compliance with ONTARIO Criteria

As described above in Sect. 8.5.2, all tested cars were evaluated for compliance with Ontario Idles criteria (O. Regul. 311, RRO 1980) shown in Table 10.1-9. Compliance of cars by model years has already been evaluated in Table 9.1-2, part B.

Table 10.1 - 9

ONTARIO Criteria

(Maximum Idle Emissions, according to 311 RRO, 1980)

		Exhaust Emissions(1)					
Model Year MY	Engine Size (CID) (5)	HC Hydrocarbons (ppmv)		CO Carbon Monoxide (% v.)		Visible Emissions (seconds) (2)	Note
		Idle	Fast Idle	Idle	Fast Idle		
-68	<141	800	800	6.0	5.0	5	(3)
	>140	600	600	5.0	3.0	5	(3)
69	<141	600	600	5.0	3.0	5	
	>140	500	500	4.0	2.0	5	
70-71	<141	500	500	4.0	2.5	5	
	>140	400	400	3.0	1.5	5	
72-74	<141	500	500	3.5	2.0	5	
	>140	400	400	2.5	1.0	5	
75-	<141	400	400	2.5	1.5	5	(4)
	>140	300	300	2.0	1.0	5	(4)

Notes:

(1) HC and CO are tested in Idle (Neutral) and Fast Idle (2450-2550 RPM), at normal operating temperature, using IR analyzer or equivalent method.

(2) Maximum duration is 5 seconds in any one-minute period. Observed in Idle and in Fast Idle, at normal operating temperature.

(3) 1968 and older MY

(4) 1975 and newer MY

(5) <141 CID means 2.29 litres or less
>140 CID means more than 2.29 litres

Table 10.1-10 demonstrates the impact of compliance with Ontario criteria on the mean EPA emission results. The last two columns show mean CO emissions in Idle and in Fast Idle. In part (a) the individual compliance groups (code 0-7) are shown. A total of 173 cars (59%) met all 4 criteria (code 0) and their mean EPA emissions (1.75/21.15/2.76) are lower than the current Canadian standards (2.0/25/3.1). Mean emissions from the other Ontario compliance groups (code 1-7) exceed Canadian standards in at least 2 pollutants (usually HC and CO). Part (b) then shows that mean HC and CO emissions of cars failing one or more Ontario criteria are about 2.5 times higher than of cars meeting all 4 criteria.

Table 10.1-11 deals with 248 newer cars (75/84 MY) only: of these 64% me tall 4 criteria. Again, mean emissions of cars failing 1 or more criteria are 2x higher in HC and 2.6 x higher in CO, while NO_x emissions do not differ significantly.

10.1.2 Compliance with CANADA Standards

Table 10.1-12 shows Canada standards (for 75-87 MY) and estimated equivalent compliance levels (for 74 and older MY), all in terms of CVS-2 and in g/mile. Individual cars were compared with these levels and their compliance indicated by code 0-7 (see Table 9.1-1A for individual cars and Table 9.1-2B, part B, for WOS 295 characteristics).

Table 10.1-13 provides mean EPA emission data for individual compliance groups. Of WOS 295 only 90 cars (31%) met all 3 standards. Mean emissions of cars failing one or more standards were almost 4x higher in HC and CO, and 1.5x higher in NO_x, see part (b). Overlap among the compliance groups is shown in Fig. 10.1-1.

Table 10.1-14 deals with 75/84 MY cars only: 85 cars (34%) met all 3 federal standards. Overlaps among the compliance groups are depicted in Fig. 10.1-2. Failed cars average 3x more HC, 3.6x more CO and 1.5x more NO_x than passed cars.

Table 10.1 - 10

Compliance with ONTARIO Criteria(1)
Fleet A (WOS 295), 1962-84 MY (295 cars)

COMPLIANCE GROUP			EPA URBAN TEST RESULTS			FUEL CONSUM.	CO	
Code (ONT)	N (Cars)	Compliance with ONTARIO Criteria(2)	HC gpm	CO gpm	NO_x gpm	(L per 100 km)	IDLE %v.	FAST IDLE %v.
		(a) Individual Compl. Groups						
0	173	Meet all 4 criteria	1.75	21.15	2.76	13.67	.44	.26
1	11	Fail HC (in ID and/or FI)	3.03	21.30	3.27	16.16	1.23	.39
2	35	Fail ID-CO only	3.11	52.07	2.92	15.06	4.08	.56
3	20	Fail HC and ID-CO	6.28	60.66	3.46	16.28	4.38	.42
4	14	Fail FI-CO only	3.86	51.70	2.29	11.89	1.94	3.10
5	2	Fail HC and FI-CO	19.27	51.24	2.88	15.37	1.40	5.20
6	24	Fail ID-CO & FI-CO	5.69	60.21	3.30	15.19	5.03	2.38
7	14	Fail HC, ID-CO & FI-CO	4.54	66.03	2.41	13.92	5.65	2.55
N/A	2	(Compliance N/A)	2.30	29.28	3.87	16.02	N/A	N/A
ALL	295		2.96	34.52	2.86	14.18	1.88	.76
		(b) Meet All vs. Fail						
0	173	Meet all 4 criteria	1.75	21.15	2.76	13.67	.44	.26
1-7,N/A	122	Fail 1 or more criteria	4.63	53.48	3.00	14.91	3.95	1.49
		(c) Meet HC vs. Fail						
0	173	Meet all 4 criteria	1.75	21.15	2.76	13.67	.44	.26
1,3,5,7	47	Fail HC(alone or in conjunction with other criteria)	5.55	52.65	3.08	15.51	3.90	1.25
2,4,6	73	Meet HC, but fail 1 or 2 other criteria	4.11	54.68	2.93	14.49	3.98	1.65
		(d) Meet ID-CO vs. Fail						
0	173	Meet all 4 criteria	1.75	21.15	2.76	13.67	.44	.26
2,3,6,7	93	Fail ID-CO(alone or in conjunction with other criteria)	4.68	58.12	3.06	15.18	4.63	1.30
1,4,5	27	Meet ID-CO, but fail 1 or more other criteria	4.67	39.28	2.73	13.88	1.61	2.15
		(e) Meet FI-CO vs. Fail						
0	173	Meet all 4 criteria	1.75	21.15	2.76	13.67	.44	.26
4-7	54	Fail FI-CO(alone or in conjunction with other criteria)	5.42	59.18	2.79	14.01	4.25	2.72
1-3	66	Meet FI-CO, but fail 1 or more other criteria	4.06	49.55	3.14	15.61	3.70	.49

Note: (1) Ontario criteria (maximum Idle emissions) in ppm HC and %v. CO are shown in Table 10.1-9 (based on Reg. 311, RRO 1980).

(2) "Fail HC" means that ID-HC and/or FI-HC criteria were exceeded.

Table 10.1 - 11

Compliance with ONTARIO Criteria(1)
Fleet A (WOS 295), 1975-84 MY (248 cars)

COMPLIANCE GROUP			EPA URBAN TEST RESULTS			FUEL CONSUM.	CO	
Code (ONT)	N (Cars)	Compliance with ONTARIO Criteria(2)	HC gpm	CO gpm	NO_x gpm	(L per 100 km)	IDLE %v.	FAST IDLE %v.
		(a) Individual Compl. Groups						
0	159	Meet all 4 criteria	1.66	18.44	2.69	13.47	.37	.23
1	6	Fail HC (in ID and/or FI)	1.74	12.47	2.64	14.56	.99	.33
2	28	Fail ID-CO only	2.80	47.04	2.71	14.40	3.85	.41
3	16	Fail HC and ID-CO	4.25	61.70	3.27	16.14	4.51	.36
4	8	Fail FI-CO only	2.34	38.52	2.02	11.19	.93	2.71
5	0	Fail HC and FI-CO	-	-	-	-	-	-
6	15	Fail ID-CO & FI-CO	2.89	46.64	3.02	14.16	4.16	2.05
7	14	Fail HC, ID-CO & FI-CO	4.54	66.03	2.41	13.92	5.65	2.55
N/A	2	(Compliance N/A)	2.30	29.28	3.87	16.02	N/A	N/A
ALL	248		2.22	29.44	2.72	13.79	1.60	.58
		(b) Meet All vs. Fail						
0	159	Meet all 4 criteria	1.66	18.44	2.69	13.47	.37	.23
1-7,N/A	89	Fail 1 or more criteria	3.22	49.10	2.77	14.36	3.76	1.21

Note: (1) Ontario criteria (maximum Idle emissions) in ppm HC and %v. CO are shown in Table 10.1-9 (based on Reg. 311, RRO 1980).

(2) "Fail HC" means that ID-HC and/or FI-HC criteria were exceeded.

Table 10.1-12

CANADA Standards
and Equivalent Compliance Levels (in g/mile, CVS - 2)

Model Year MY	CANADA Standards or equivalents HC	CO	NO_x	Note
67 & older	8.7	87	4.65	(1)
68 - 69	6.0	34	4.0	(2)
70 - 71	4.1	34	4.0	(1)
72	3.0	28	4.0	(1)
73 - 74	3.0	28	3.1	(1)
75 - 87	2.0	25	3.1	(3)

Notes: (1) Emission levels and standards for pre-1975 models were originally established in terms of other test procedures than the current CVS-2 (see Table 2.2-1). These equivalent levels are estimates (in g/mi, CVS- 2) by EPA and/or by California ARB. They were used to evaluate compliance with CANADA standards in Table 10.1-13.

(2) Equivalent levels for HC and NO_x were estimated by MOE (VEU).

(3) Official canadian emission standards (in terms of CVS-2).

Table 10.1 - 13

Compliance with CANADA Standards(1)
Fleet A (WOS 295), 1962-84 MY (295 cars)

COMPLIANCE GROUP			EPA URBAN TEST RESULTS			FUEL CONSUM.	CO	
Code (CAN)	N (Cars)	Compliance with CANADA Standards	HC gpm	CO gpm	NO_x gpm	(L per 100 km)	IDLE %v.	FAST IDLE %v.
(a) Individual Compl. Groups								
0	90	Meet all 3 standards	1.07	11.92	2.06	12.90	.46	.33
1	17	Fail HC only	2.83	18.21	2.10	13.69	.75	.73
2	21	Fail CO only	2.35	47.60	2.46	14.42	2.16	.65
3	67	Fail HC & CO	5.39	62.98	2.06	14.87	3.56	1.55
4	32	Fail NO_x only	1.26	10.64	4.11	12.88	.31	.19
5	10	Fail HC & NO_x	2.70	15.94	4.55	14.03	.70	.41
6	10	Fail CO & NO_x	2.45	45.23	4.65	15.57	2.99	1.32
7	48	Fail all 3 standards	4.56	54.79	4.34	16.32	3.54	.88
ALL	295		2.96	34.52	2.86	14.18	1.88	.76
(b) Meet All vs. Fail								
0	90	Meet all 3 standards	1.07	11.92	2.06	12.90	.46	.33
1-7	205	Fail 1 or more standards	3.77	44.45	3.21	14.75	2.51	.96
(c) Meet HC vs. Fail								
0	90	Meet all 3 standards	1.07	11.92	2.06	12.90	.46	.33
1,3,5,7	142	Fail HC(alone or in conjunction with other standards)	4.62	51.54	3.01	15.16	3.03	1.15
2,4,6	63	Meet HC, but fail CO and/or NO_x	1.81	28.45	3.65	13.82	1.35	.52
(d) Meet CO vs. Fail								
0	90	Meet all 3 standards	1.07	11.92	2.06	12.90	.46	.33
2,3,6,7	146	Fail CO(alone or in conjunction with other standards)	4.50	56.86	3.05	15.33	3.29	1.18
1,4,5	59	Meet CO, but fail HC and/or NO_x	1.97	13.72	3.61	13.31	.50	.38
(e) Meet NO_x vs. Fail								
0	90	Meet all 3 standards	1.07	11.92	2.06	12.90	.46	.33
4-7	100	Fail NO_x(alone or in conjunction with other standards)	3.13	35.82	4.32	14.91	2.16	.66
1-3	105	Meet NO_x, but fail HC and/or CO	4.39	52.66	2.15	14.59	2.84	1.24

Note: (1) Canada standards (for 1975-84 MY) and equivalent unofficial compliance levels (for 1962-74 MY) in g/mile, CVS-2, are shown in Table 10.1-12.

Table 10.1-14

Compliance with CANADA Standards(1)

Fleet A (WOS 295), 1975-84 MY (248 cars)

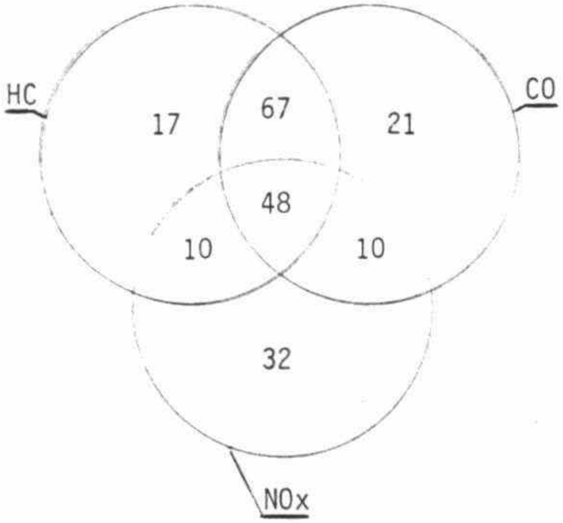
COMPLIANCE GROUP			EPA URBAN TEST RESULTS			FUEL CONSUM. (L per 100 km)	CO	
Code (CAN)	N (Cars)	Compliance with CANADA Standards	HC gpm	CO gpm	NO_x gpm		IDLE %v.	FAST IDLE %v.
	(a) Individual Compl. Groups							
0	85	Meet all 3 standards	.97	10.92	2.01	12.80	.37	.25
1	14	Fail HC only	2.43	16.13	2.03	13.58	.68	.55
2	15	Fail CO only	1.75	31.04	2.11	12.51	1.68	.50
3	55	Fail HC & CO	3.85	57.97	2.00	14.31	3.42	1.34
4	30	Fail NO_x only	1.18	10.65	4.04	12.81	.32	.18
5	10	Fail HC & NO_x	2.70	15.94	4.55	14.03	.70	.41
6	2	Fail CO & NO_x	1.59	36.29	4.40	17.01	2.45	.90
7	37	Fail all 3 standards	3.51	52.51	4.28	16.43	3.30	.61
ALL	248		2.22	29.44	2.72	13.79	1.60	.58
	(b) Meet All vs. Fail							
0	85	Meet all 3 standards	.97	10.92	2.01	12.80	.37	.25
1-7	163	Fail 1 or more standards	2.88	39.10	3.09	14.30	2.25	.76

Note: (1) Canada standards (for 1975-84 MY) and equivalent unofficial compliance levels (for 1962-74 MY) in g/mile, CVS-2, are shown in Table 10.1-12.

Figure 10.1-1

Overlap Among CANADA Compliance Groups

(WOS 295, 1962-84 MY, 295 Cars; See Table 10.1-13)

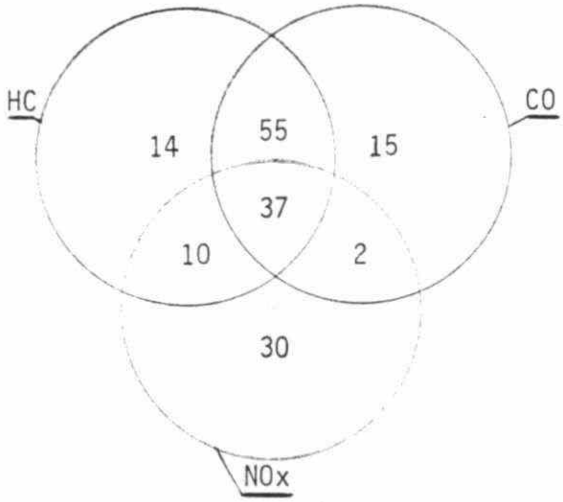


	Cars	% rel.
Total sample	295	100.0
Meet all 3 standards	90	30.5
Fail 1 or more standards	205	69.5
Fail HC	142	48.1
Fail CO	146	49.5
Fail NO_x	100	33.9

Figure 10.1-2

Overlap Among CANADA Compliance Groups

(WOS 295, 1975-84 MY, 248 Cars; see Table 10.1-14)



	Cars	% rel.
Total sample	248	100.0
Meet all 3 standards	85	34.3
Fail 1 or more standards	163	65.7
Fail HC	116	46.8
Fail CO	109	44.0
Fail NO_x	79	31.9

It is worth noting, that among the 163 failed cars there are 31 US-specification cars. Theoretically, these cars were supposed to meet not just the Canadian standards, but also the more stringent U.S. standards.

In Table 10.1-15, the emission performance of US-specification cars is investigated further: for the 75/84 MY group as a whole and for individual model years. The 53 US-specification cars seem to be, on the average, slightly higher in HC and in CO (possibly due to higher mileage readings) and quite a bit lower in NO_x than the CAN (= non-US) specification cars. Results for individual model years do not fully clarify the situation. For this reason in Table 10.1-16 the 75/84 MY group is divided into subgroups reflecting changes in U.S. standards (while Canadian standards were unchanged).

When comparing the emissions of US- to CAN-specification cars, in the 75/79 MY the US-cars are again slightly higher in HC and CO. The more recent US-cars are then significantly lower (the 80/84 MY in HC and CO, the 81/84 MY in NO_x). Another variable in column h, shows the ratio of results to standards. Except for one subgroup (NO_x in 75/76 MY), these ratios for US-cars are always higher than for the CAN-cars. This indicates that US-specification cars operated in Ontario are not achieving their full low-emission potential and/or are deteriorating faster.

10.1.3 Predictive Qualities of Ontario Idles Test

Results of the Idles Test (HC and CO in Idles, see code: ONTARIO) were also evaluated for their capability to predict exceedances of CANADA standards (and equivalents). Complete picture is presented in Table 10.1-17.

First, we must realize that the Idles Test, which involves HC and CO only, is not relevant to Canada standard for NO_x. Simple correlation coefficients between COIDLE or COFASTID on one side and NOEPWEIG on the other (see Tables 10.1-1 to -3, above) are either below 0.14 or statistically insignificant or both. For this reason, compliance with NO_x (in column CANADA) was eliminated from the above Table 10.1-17 (i.e., code 4 became 0, code 5 became 1, etc.). The Contingency Table 10.1-18 was generated showing vehicles passed or failed by Idles (HC, CO) and by FTP (HC, CO).

Table 10.1 - 15

Mean Emission Levels - U.S. vs. Canada - specification Cars(1)
Fleet A (WOS 295), by MY

MODEL YEAR	N (Cars)	SPECIF. Group (1)	CID	MILEAGE (Miles x1000)	EPA URBAN TEST RESULTS			FUEL CONSUM. (L per 100 km)	CO	
					HC gpm	CO gpm	NO_x gpm		IDLE %v.	FAST IDLE %v.
75	12	CAN	300	67.0	3.00	42.36	3.84	17.80	2.45	.55
	6	US	264	84.3	3.76	66.31	2.93	16.67	4.00	1.90
76	14	CAN	286	69.0	3.07	48.74	2.68	17.04	2.92	1.12
	7	US	268	67.0	2.90	45.32	3.09	15.16	3.06	.46
77	22	CAN	279	58.0	3.09	38.45	3.43	14.95	2.73	.70
	8	US	276	62.1	2.75	30.13	2.10	15.36	.98	.49
78	26	CAN	225	42.2	2.96	40.00	2.91	13.65	2.32	.90
	10	US	257	63.2	3.49	50.02	2.60	14.73	3.41	.46
79	29	CAN	236	33.6	2.04	25.29	2.89	13.17	1.08	.55
	5	US	270	45.6	1.56	19.82	2.45	15.13	.21	.17
80	21	CAN	214	25.3	2.83	33.68	2.54	13.15	1.46	.44
	9	US	221	24.4	.84	10.91	1.74	14.02	.66	.09
81	23	CAN	211	13.4	1.20	17.90	2.74	12.45	.99	.38
	2	US	95	16.5	.47	2.86	.65	9.58	1.33	.93
82	24	CAN	176	13.3	1.31	16.99	2.21	11.54	.68	.69
	1	US	120	6.0	.22	3.71	1.06	10.24	.05	.05
83	17	CAN	191	10.9	.96	9.69	2.91	12.12	.36	.19
	3	US	241	7.3	1.23	15.85	1.73	14.19	.05	.05
84	7	CAN	168	5.6	1.21	8.79	2.41	11.49	.49	.29
	2	US	200	4.0	1.42	14.30	1.61	12.61	.23	.73
75-84	195	CAN	228	33.3	2.20	28.53	2.84	13.56	1.54	.60
75-84	53	US	245	49.5	2.32	32.81	2.28	14.63	1.84	.53

Notes: (1) US-specification cars (US) are those equipped with EPA certification label and meeting U.S. (49-states) emission standards, i.e. SPECIF code: U.

Canada-specification cars (CAN) are defined in this Table as "non- US", i.e. all other cars (bearing Canada, Tune-up labels or no labels at all), i.e. SPECIF codes: C, L, T, -.

Table 10.1 - 16

Mean Emissions and Standards - U.S. vs. Canada - specification Cars (1) Fleet A (WOS 295), by MY Group

POLLUTANT	MY Group (2)	SPECIF. Group (1)	EMISSION STAND. gpm	N (Cars)	MILEAGE (Miles x1000)	EPA URBAN TEST RESULTS (Mean,gpm)	RATIO of TEST RESULT to STANDARD	NOTE
a	b	c	d	e	f	g	h=g/d	i
HC	75-79	CAN	2.0	103	49.7	2.75	1.38	
		US	1.5	36	64.8	2.99	2.00	
	80-84	CAN	2.0	90	15.0	1.57	.79	(3)
		US	.41	17	17.0	.90	2.20	
CO	75-79	CAN	25.0	103	49.7	37.0	1.48	
		US	15.0	36	64.8	43.2	2.88	
	80-84	CAN	25.0	92	15.0	19.1	.76	
		US	7.0/3.4	17	17.0	10.8	2.08	(4)
NO_x	75-76	CAN	3.1	26		3.22	1.04	
		US	3.1	13		3.02	.97	
	77-80	CAN	3.1	98		2.94	.95	
		US	2.0	32		2.21	1.11	
	81-84	CAN	3.1	71		2.57	.83	
		US	1.0	8		1.35	1.35	

Notes: (1) US-specification cars (US) are those equipped with EPA certification label and meeting U.S. (49-states) emission standards, i.e. SPECIF code: U.

Canada-specification cars (CAN) are defined in this Table as "non-US", i.e. all other cars (bearing Canada, Tune-up labels or no labels at all), i.e. SPECIF codes: C, L, T, -.

(2) MY groups reflect changes in US standards.

(3) Two cars have HC results missing.

(4) Assuming that 50% of US-specification cars got exemption to 7.0 gpm CO.

Table 10.1-17

WOS 295 Cross-Compliance of ONTARIO with CANADA Standards

ONTARIO (CODE)	CANADA (CODE)	FREQUENCY (CARS)	CUM. FREQ (CARS)	PERCENT (% r.)	CUM. PERCENT (% r.)
*	1	1	-	-	-
*	7	1	-	-	-
0	0	80	80	27.304	27.304
0	1	10	90	3.413	30.717
0	2	12	102	4.096	34.812
0	3	15	117	5.119	39.932
0	4	30	147	10.239	50.171
0	5	9	156	3.072	53.242
0	6	6	162	2.048	55.290
0	7	11	173	3.754	59.044
1	0	4	177	1.365	60.410
1	1	3	180	1.024	61.433
1	3	1	181	0.341	61.775
1	4	1	182	0.341	62.116
1	5	1	183	0.341	62.457
1	6	1	184	0.341	62.799
2	0	3	187	1.024	63.823
2	2	7	194	2.389	66.212
2	3	13	207	4.437	70.648
2	4	1	208	0.341	70.990
2	7	11	219	3.754	74.744
3	3	9	228	3.072	77.816
3	7	11	239	3.754	81.570
4	0	2	241	0.683	82.253
4	1	1	242	0.341	82.594
4	2	1	243	0.341	82.935
4	3	8	251	2.730	85.666
4	7	2	253	0.683	86.348
6	1	1	254	0.341	86.689
6	3	1	255	0.341	87.031
6	0	1	256	0.341	87.372
6	1	1	257	0.341	87.713
6	2	1	258	0.341	88.055
6	3	10	268	3.413	91.468
6	6	3	271	1.024	92.491
6	7	8	279	2.730	95.222
7	3	10	289	3.413	98.635
7	7	4	293	1.365	100.000

Note: * ONTARIO code not available (Idels Test results missing)

NOEPWEIG on the other (see Tables 10.1-1 to -3, above) are either below 0.14 or statistically insignificant or both. For this reason, compliance with NO_x (in column CANADA) was eliminated from the above Table 10.1-17 (i.e., code 4 became 0, code 5 became 1, etc.). The Contingency Table 10.1-18 was generated showing vehicles passed or failed by Idles (HC, CO) and by FTP (HC, CO).

Table 10.1-18

WOS 295 Contingency Table, by MY Group

COMPLIANCE with FTP (CAN)	with Idles (ONT)	Compl. Group (see Note)	All MY 62/84 Cars	%	Newer MY 75/84 Cars	%	Older MY 62/74 Cars	%
PASS	**PASS**	PP	110	37.5	106	43.1	4	8.5
PASS	**FAIL**	E_c	12	4.1	9	3.7	3	6.4
FAIL	**PASS**	E_o	63	21.5	53	21.5	10	21.3
FAIL	**FAIL**	FF	108	36.9	78	31.7	30	63.8
		All	293	100.0	246	100.0	47	100.0

Note: PP correctly passed by both test procedures, in HC and CO.
E_c error of commission, i.e. incorrectly failed by Idles Test.
E_o error of omission, i.e. incorrectly passed by Idles Test although car exceeds one or both FTP standards.
FF correctly failed by both test procedures, in HC and/or CO.

Idles Test proves to be an excellent tool for identifying compliance of cars with CANADA standards (HC, CO): 74.4% of 293 cars in WOS 295 were either correctly passed or correctly failed (PP plus FF). In 21.5% of cases Idles Test passed a vehicle, which then failed FTP (= error of omission, E_o). Only 4.1% of cars were incorrectly failed by Idles (= error of commission, E_c).

Results for subgroups by MY (i.e. 75/84 and 62/74) are very similar. Error of omission E_o, which is fairly constant, reflects the stringency of Ontario Idles criteria. A lower E_o could be achieved by lowering cut- points (criteria).

10.2 Excessive Emitters (in WOS 295)

Visual investigation of plots shown previously, mainly HC and CO vs. MY in Fig. 9.1-1A and -2A, indicate the presence of a small number of cars with very high HC and/or CO emissions (e.g. car #352 with 25.6 g/mi HC and 247.5 g/mi CO). Such extreme observations are in statistics usually called outliers. A popular procedure for their identification is to compare all observations (within the same population) with the total of sample mean M plus 3 sample standard deviations S.D., i.e. M + 3 S.D. (L53). This method was deemed sufficient for our purposes.

Table 10.2-1

Criteria for Identification of Excessive Emitters

	Criterion (in g/mile)			
MY	HC	CO	NO_x	Note
75-newer	(Mean + 3 S.D.) for its own or any previous MY group, whichever is lower.			(1)
74-older	10	100	8	(2)

Notes: (1) Previous MY groups were considered for consistency. It was felt that the newer cars should, on the average, be lower in emissions than the older, less controlled cars with more mileage.

(2) Criteria were set arbitrarily as not enough cars were tested in individual MY.

The application of the above criteria to WOS 295 identified the following number of excessive cars: 4 in HC only, 10 in CO only, 6 in HC and CO, and 2 in NO_x only. Surprisingly, some of these cars were barely run-in (e.g. #39, 179 and 257), with mileages between 4000-6000 miles. The latter two NO_x outliers are test car #172 with 7.2 g/mi and #257 with 5.3 g/mi.

There are 20 cars excessive in HC and/or CO, and their identifiability by the Ontario Idles Test was further investigated (Note: Any further reference to excessive emitters or EE means cars excessive in HC and/or CO, unless noted otherwise).

Excessive emitters are listed in Tables 10.2-2 and -3 and plotted in Fig. 10.2-1 to -3. Their complete mass-emission results (by test car) are listed in Table 10.2-4A and -4B. (App. F).

Table 10.2-2 shows, that out of 20 excessive emitters, 18 were identified by Ontario Idles criteria (HC, CO) and 1 car (# 352) by the emission of smoke (soot). Only 1 car passed all five Ontario criteria while being greatly excessive in CO (car #247 with 170.8 g/mi). Thus, the error of omission among excessive emitters was 5%.

Tables 10.2-5 to -6 (App.F) and 10.2-7 show simple statistics for subsets of WOS 295, i.e. for 20 (6.8%) excessive emitters and for the remaining 275 (93.2%) cars. Excessive emitters (EE) are in the average almost 6x higher in HC and almost 4x higher in CO than non-excessive (NE) cars. They seem to constitute a separate sample population. Their relative frequency in a sample affects the mean emissions greatly. It is therefore of great importance to estimate their true relative frequency in the Ontario car population. The current surveillance program most definitely underestimates their share, due to the pre-selection of cars discussed in Sect. 3.2 above: sampling in Greater Metro area only, exclusion of unsafe and smoking cars (i.e. potential high emitters).

The results from the Ontario 1982 spot-checking program were therefore reviewed for the presence of cars with very high Idles emissions. This procedure, though somewhat subjective, indicated that approximately 15% of spot-checked cars can be suspected of being excessive emitters. As about 70% of cars spot-checked in 1982 were sampled in Metro Toronto, it has been estimated that the percentage of EE in Ontario population could be even higher, closer to 20%. Table 10.2-8 summarizes these findings. Table 10.2-9 then provides a more realistic estimate of the impact of EE cars on HC and CO emissions.

Table 10.2 - 2

Excessive Emitters (in HC and/or CO)
Fleet A (WOS 295), FTP-75 and Idles Test Results

TEST CAR #	MY	EPA Urban Test (EPWEIG)			Ontario Idles Test Emissions					Note
		HC gpm	CO gpm	NO_x gpm	CO IDLE %v.	CO FASTID %v.	HC IDLE ppm	HC FASTID ppm	VISIBLE EMISS. (SOOT)	
a	b	c	d	e	f	g	h	i	j	k
290	66	7.6	**144.8**	4.0	**5.40**	1.20	440	160		
300	68	**59.2**	**114.2**	.4	**6.80**	**3.80**	300	180	**SOOT**	(1)
299	68	6.5	**147.3**	1.9	**10.00**	**4.60**	560	380		
314	71	**13.3**	**109.8**	1.1	3.20	**2.80**	440	240		
245	71	**32.9**	76.1	3.6	2.60	**7.00**	**1940**	**2000**		
291	73	5.5	**134.8**	1.2	2.50	**1.80**	100	60		
247	73	N/A	**170.8**	2.8	2.00	.60	120	60		(2)(3)
233	74	**10.6**	29.3	6.0	**3.50**	.90	**2000**	**2000**		
190	74	**33.5**	44.4	4.1	**4.10**	.35	**1510**	**1450**		
242	75	**8.2**	**167.6**	2.8	**9.00**	1.00	**420**	100		
274	76	4.9	**109.6**	1.1	**8.60**	**4.60**	**480**	400		
309	76	6.3	**109.8**	2.6	**6.40**	.20	**620**	300		
367	77	5.0	**100.5**	.5	**2.60**	**3.00**	**420**	300		
313	77	**7.2**	67.0	5.4	**4.40**	.80	**740**	80		
306	78	**8.1**	**140.1**	.7	**3.40**	.20	340	200		
277	78	**7.0**	**109.2**	5.4	**6.80**	**1.80**	**920**	300		
166	79	4.9	**82.0**	1.7	**5.20**	**3.20**	**420**	220		
39	80	4.0	**83.4**	3.1	**2.60**	.30	120	40		
352	80	**25.6**	**247.5**	.5	1.40	.60	140	60	**SOOT**	(1)(2)
179	82	2.0	**64.4**	.7	1.40	**2.80**	140	140		
ALL										
20 cars	66/82	13.3	112.6	2.5	4.59	2.08	609	434		
IN TWO MY GROUPS										
9 cars	66/74	21.1	107.9	2.8	4.45	2.56	823	726		
11 cars	75/82	7.6	116.5	2.2	4.71	1.68	433	195		

Notes:
(1) Emission of black smoke (soot) was noted.
(2) HC and CO emissions in Idles are within Ontario criteria.
(3) HC emissions in FTP-75 not available due to failure of HC analyzer.

Table 10.2-7

WOS 295 Arith. Means (with and without EE)

					EPA Urban Test Results				CO	
Group	N cars	DYNO Inertia lbs	Engine CID	Mileage miles	HC g/mi	CO g/mi	NO_x g/mi	Fuel Consum. L/100 km	Idle % v.	Fast Idle % v.
All	295 (291)	3576	238.5	46,298	2.96	34.52	2.86	14.18	1.88	.76
EE	20 (19)	3838	268.3	86,950	13.27	112.63	2.47	18.01	4.59	2.08
NE	275 (272)	3557	236.3	43,342	2.24	28.84	2.88	13.90	1.68	.67

Notes: EE Excessive Emitters (in HC and/or CO, FTP).
NE Non-excessive Emitters (i.e. other cars in sample).

Table 10.2-8

Relative Frequency of Excessive Emitters in Ontario

	Surveillance Program (Mass-emissions test)		Spot-checking Program (Idles Test)	
	WOS 295	OS 200	G.Metro/Ontario 1982 TY	Ontario 1982 TY
EE, rel. freq.	6.8%	9.0%	estim. 15%	estim. 20%
BIAS in sampling: (a) Gr. Metro cars	100%	100%	67%	N/A
(b) Unsafe/smoking cars excluded	all	all	some	N/A
(c) Volunteers	100%	100%	appr. 20%	N/A
(d) Other bias	-	Hand picked from WOS 295	-	N/A

Table 10.2-9

WOS 295 Impact of Excessive Emitters on Means

			Assuming 15% of EE			Assuming 20% of EE		
Pollutant	Sub-group	EPA Urban g/mi	Weigh. Factor	Contribution g/mi	% rel.	Weigh. Factor	Contribution g/mi	% rel.
HC	EE	13.27	0.15	1.99	51.1	0.20	2.65	59.7
	NE	2.24	0.85	1.90	48.9	0.80	1.79	40.3
	All	2.96		3.89	100.0		4.44	100.0
CO	EE	112.63	0.15	16.89	40.8	0.20	22.53	49.4
	NE	28.84	0.85	24.51	59.2	0.80	23.07	50.6
	All	34.52		41.40	100.0		45.60	100.0

Notes: EE Excessive Emitters (in HC and/or CO, FTP).
NE Non-excessive Emitters (i.e. other cars in sample).

Using WOS 295 results and assuming that 15% of the cars in Ontario are EE, we can conclude that this relatively small fraction of cars is responsible for about 51% of HC and for 41% of CO from all cars.

To illustrate the possible impact of the control of emissions from these EE cars alone (by an I/M program), let us assume the following conservative figures: 15% of EE; their 80% identification; control of identified EE to a mean HC level that is just 2x higher (not 6x), and to a mean CO level that is also 2x higher (not 4x) than the NE group. Such control program would result in minimum overall reductions of 27% in HC and of 16% in CO. Further reductions would follow from the control of other identified high emitters in the NE group.

Note: EE cars impact greatly on mean emissions and it is important to accurately estimate their relative frequency in the population. Current sampling procedure of the Ontario surveillance program is biased (volunteered, safe and non-smoking cars from Gr. Metro). Unless this sampling can be made completely random and obligatory, another parallel sampling program (e.g. using obligatory short-tests) is necessary. One possibility is to revive the spot-checking program, to operate it during one summer and to sample at random and province-wide about 2000 cars.

10.3 Fleet B: OS 200

The OS 200, selected from WOS 295, was matched closely to the requirements of Target List 200. Considering the total size of the sample (200), the deviations (indicated in Tables 9.2-1A and -2C) were minor.

Sample characteristics (Tables 9.2-2A and -2B) provide detailed insight into OS 200 composition. Again, as in WOS 295, there is a large presence (42%) of rental cars in 1982 MY. (Also, one should keep in mind the sampling biases: hand-picked volunteers from Greater Metro and exclusion of unsafe and smoking vehicles, see Table 10.2-8).

Arithmetic means (Tables 9.2-4A and -4B) show a general trend to higher emissions and to higher FC with older models. The relative frequency of excessive emitters (EE) in OS 200 is slightly higher (9.0%) than in WOS (6.8%). (Presence of EE cars is noticeable in Figures 9.2-1, -2 and -7).

Correlation coefficients, shown in Table 10.3-1, are similar to those for WOS 295 (in Table 10.1-1). They are very high (0.84 or better) for correlations between FC and INERTIA, between FC and CID, and between weighted EPA results, individual phases of the FTP and of the MFTP.

10.3.1 Compliance with ONTARIO Criteria

Compliance by MY has been shown in Table 9.2-2B, Part B, above. Compliance of the entire Fleet B is as follows: 48% failed one or more of the criteria (ID-HC, FI-HC, ID-CO, FI-CO), 38% failed Idle-CO (alone or in combinations), 24% failed Fast Idle-CO (alone or in combinations) and 17% failed one or both HC criteria. The 48% fail rate corresponds very well with a 48-53% average yearly fail rate established by MOE spot-checking programs in 1979- 1982 TY.

10.3.2 Compliance with CANADA Standards

Of all cars in OS 200, 74.5% failed one or more CANADA standards (or equivalents): 51.0% failed HC (alone or in combinations), 55.5% failed CO and 34.5% failed NO_x (alone or in combinations). A significant proportion (17.0%) failed all three standards. Older MY cars (62/74) show even higher fail rates, especially in CO, see Table 10.3-2 below.

Table 10.3-1

Simple Correlation Coefficients
Fleet B (OS 200), 1962-82 MY (200 cars)

	TEST/CAR PARAMETERS				EPA URBAN TEST RESULTS			
VARIABLE	INERTIA	MODELYR	CID	MILEAGE	HCEP-WEIG	COEP-WEIG	NOEP-WEIG	FCEP-WEIG
1	2	3	4	5	6	7	8	9
HCEPWEIG	.15	-.39	*	.43	1.00	.51	*	.30
COEPWEIG	.21	-.53	.21	.57	.51	1.00	*	.50
NOEPWEIG	.32	-.28	.26	.29	*	*	1.00	.21
FCEPWEIG	.86	-.43	.87	.50	.30	.50	.21	1.00
COIDLE	*	-.50	*	.53	.31	.58	.15	.14
COFASTID	-.19	-.52	-.22	.42	.36	.39	*	*
HCEPCOLD	.22	-.40	.16	.44	.94	.50	*	.35
EPSTAB	.13	-.36	*	.39	.99	.48	*	.26
EPHOT	.17	-.40	.11	.45	.95	.54	*	.33
TBHOT	.17	-.41	.11	.48	**.92**	.54	*	.32
TBSTAB	.13	-.39	*	.43	**.99**	.51	*	.28
COEPCOLD	.25	-.49	.25	.51	.38	.84	*	.50
EPSTAB	.18	-.51	.20	.56	.50	.98	*	.48
EPHOT	.17	-.47	.16	.51	.54	.96	*	.44
TBHOT	.16	-.46	.14	.49	.71	**.84**	-.13	.39
TBSTAB	.14	-.49	.14	.51	.72	**.84**	*	.38
NOEPCOLD	.29	-.20	.24	.20	*	*	.88	.15
EPSTAB	.30	-.24	.22	.25	*	*	.94	.18
EPHOT	.31	-.33	.28	.33	*	*	.96	.25
TBHOT	.35	-.30	.31	.34	*	*	**.92**	.25
TBSTAB	.33	-.26	.26	.29	*	*	**.93**	.21
FCEPCOLD	.85	-.41	.86	.48	.24	.47	.21	.97
EPSTAB	.85	-.43	.86	.51	.32	.52	.22	.99
EPHOT	.87	-.40	.87	.48	.29	.48	.20	.99
TBHOT	.86	-.45	.85	.52	.39	.47	.17	**.96**
TBSTAB	.78	-.46	.78	.52	.46	.50	.18	**.93**

* absolute value of r is below 0.10.

Note: Correlations with an absolute value of $r > 0.139$ are statistically significant at the 95% confidence level.

Table 10.3-2

OS-200 Compliance with CANADA Standards by MY Group, % relat. (1)(2)

MY Group (= 100%)	Passed all 3 standards	Failed (alone or in combinations) HC	CO	NO_x	Failed all 3 standards
75/82	28.9	50.3	48.4	33.3	15.7
62/74	12.2	53.7	82.9	39.0	22.0
All	25.5	51.0	55.5	34.5	17.0

Notes: (1) Based on Table 9.2-2, Part B.
(2) Standards (or equivalents) are shown in Table 10.1-12.

Table 10.3-3 compares fail rates for CANADA and ONTARIO by MY. There is a clear trend to higher fail rates with older models. For better comparison to ONTARIO fail rates, which are based on HC and CO only, the compliance with the NO_x standard was eliminated from columns f and g. Such modified CANADA fail rates are closer to ONTARIO rates, particularly for the recent models.

(Note: Predictive qualities of the Idles Test are discussed in Sect. 10.1.3. A separate analysis of OS 200 was not attempted).

10.3.3 Excessive Emitters (in OS 200)

Out of the 20 excessive emitters found in WOS 295 (see Table 10.2-2), 17 are present in OS 200 (all except # 313, 277 and 39). In addition, there is clone #9290. In total, OS 200 contains 18 EE (9.0%).

Table 10.3-4 shows arith. means for subsets of OS 200: EE cars are 6x higher in HC and almost 4x higher in CO than NE cars.

Table 10.3-3

OS 200 Fail Rates by MY

Model Year MY	Cars (in MY)	CANADA (HC, CO, NO) Fail 1 or more standards Cars	%	ONTARIO (HC, CO) Fail 1 or more criteria Cars	%	CANADA (HC, CO) Fail 1 or both standards Cars	%
Column	a	b	c	d	e	f	g
1982	19	8	42	5	26	6	32
81	23	14	61	6	26	7	30
80	25	10	43	8	32	9	36
79	22	15	68	5	23	10	46
78	22	21	95	11	50	18	82
77	18	15	83	12	67	15	83
76	16	16	100	10	63	15	94
75	14	14	100	7	50	13	93
74	11	10	91	9	82	10	91
73	8	8	100	5	63	8	100
72	6	5	83	4	67	5	83
71	4	4	100	3	75	4	100
70	3	2	67	3	100	2	67
69	1	1	100	0	0	1	100
68	2	2	100	2	100	2	100
62/67	6	4	67	6	100	4	67
All	200	149	75	96	48	129	65
75/82	159	113	71	64	40	93	59
62/74	41	36	88	32	78	36	88

Table 10.3-4

OS 200 Arith. Means (with and without EE)

Group	N cars	DYNO Inertia lbs	Engine CID	Mileage miles	EPA Urban Test Results HC g/mi	CO g/mi	NO_x g/mi	Fuel Consum. L/100 km	CO Idle % v.	CO Fast Idle % v
All	200 (198)	3549	238.9	50,365	3.40	39.46	2.85	14.26	2.23	.97
EE	18 (17)	3792	268.6	94,333	14.21	118.77	2.19	18.06	4.64	2.21
NE	182 (181)	3525	236.5	46,016	2.39	31.62	2.92	13.88	1.99	.84

Table 10.3-5 indicates that, similar to findings for WOS 295, EE in OS 200 responsible for 51% of HC and for 40% of CO from all cars.

Table 10.3-5

OS 200 Impact of Excessive Emitters on Means

			Assuming 15% of EE			Assuming 20% of EE		
Pollutant (FTP)	Sub-Group	EPA Urban g/mi	Weigh. Factor	Contribution g/mi	% rel.	Weigh. Factor	Contribution g/mi	% rel.
HC	EE	14.21	0.15	2.13	51.2	0.20	2.84	59.8
	NE	2.39	0.85	2.03	48.8	0.80	1.91	40.2
	All	3.40		4.16	100.0		4.75	100.0
CO	EE	118.77	0.15	17.82	39.9	0.20	23.75	48.4
	NE	31.62	0.85	26.88	60.1	0.80	25.30	51.6
	All	39.46		44.70	100.0		49.05	

Notes: EE Excessive Emitters (in HC and/or CO, FTP).
NE Non-excessive Emitters (i.e. other cars in sample).

Also, relative frequency of EE in OS 200 affects the estimated emission rates (for mid-1982):

EE Share (in OS 200)	Emission Rate, g/mile HC	 CO
0% (calculated)	2.39	31.62
9% (as found)	3.40	39.46
15% (estimated)	4.16	44.70
20% (estimated)	4.75	49.05

10.3.4 Ontario and U.S. Emission Rates

As a result of lenient Canada standards, Ontario emission rates for 1975-84 MY are expected to be higher than U.S. rates. OS 200 data, together with 83-84 MY data from WOS 295, are reviewed for this purpose, after eliminating excessive emitters in HC and CO (i.e. EE cars).

Resulting emission rates are shown in Table 10.3-6. Also included are estimated U.S emission rates, calculated for each MY at corresponding mileage levels using EPA formulae (L55) (Note: This comparison is only approximate due to different procedures for the preparation of Ontario and EPA rates; e.g., Ontario data contain some cars with relatively increased NO_x emissions, which under EPA procedures might be excluded).

Table 10.3-6

Ontario and U.S. Emission Rates (1)

MY	Cars	Mileage x1000 miles	Ontario Emission Rates(1) HC g/mi	CO g/mi	NO_x g/mi	FC (2)	U.S. Emission Rates(3) HC g/mi	CO g/mi	NO_x g/mi	
75	13	75.9	2.94	42.35	2.26	16.52	3.49	41.85	2.73	(4)
76	14	59.7	2.91	45.41	2.66	15.43	3.02	37.24	2.67	(4)
77	17	53.5	2.84	34.50	2.22	14.35	2.84	35.45	2.23	(4)
78	21	42.1	2.99	40.24	3.06	13.64	2.51	32.21	2.11	(4)
79	21	33.4	1.79	21.53	2.67	13.38	2.26	29.71	2.02	(4)
80	24	26.1	1.36	16.48	2.98	12.57	1.05	13.60	1.82	(4)
81	23	14.0	1.13	16.38	3.02	12.28	.66	9.45	.96	(4)
82	18	11.5	1.25	13.95	3.66	11.35	.61	8.37	.92	(4)
83	20	10.4	1.00	10.62	2.73	12.43	.59	7.86	.91	(5)
84	9	5.2	1.25	10.01	2.23	11.73	.49	6.44	.83	(5)

Notes:
(1) Ontario emission rates calculated after elimination of excessive cars in HC,CO.
(2) Fuel consumption (in litres/100 km).
(3) Calculated US emission rates at the same mileage levels (see L55, Table 1.1.1A).
(4) Based on OS 200 data (without EE cars)
(5) Based on WOS 295 data (no EE cars present)

Table 10.3-7 then shows ratios of Ontario vs. U.S. emission rates. As background, it also shows ratios of Canada to U.S. emission standards and the percentage of US-specification cars in sample.

Starting with 80 MY, Ontario rates are consistently higher than U.S. rates by 20% to 200%. Ratios of Ontario/US rates correlate very well with ratios of Canada/US emission standards: coefficient r approximates 0.82 for HC, 0.85 for CO and 0.96 for NO_x. Sudden increases in ratios of standards (with 80 MY for HC, and with 81 MY for CO and NO_x) are clearly reflected in ratios of emission rates (50% of US-specification cars present in 80 MY have a mitigating effect on the HC ratio; i.e., 1.30). A sudden drop in percentages of US-cars in sample (with 81 MY) is also noticeable.

Table 10.3-7

Ratios of Ontario/US Emission Rates (after elimination of excessive emitters)

MY	Ratio of Canada/US emission standards(1)			US-spec. cars in sample (2)	Ratio of Ontario/US emission rates(3)			Note
	HC	CO	NO_x	% rel.	HC	CO	NO_x	
1975	1.3	1.7	1.0	33	.84	1.01	1.34	(4)
6	1.3	1.7	1.0	67	.96	1.22	1.13	(4)
7	1.3	1.7	1.6	33	1.00	.97	1.34	(4)
8	1.3	1.7	1.6	47	1.19	1.25	1.26	(4)
9	1.3	1.7	1.6	20	.79	.73	1.51	(4)
80	4.9	3.6	1.6	50	1.30	1.21	1.22	(4)
81	4.9	7.4	3.1	10	1.72	1.73	2.77	(4)
82	4.9	7.4	3.1	6	2.06	1.67	2.46	(4)
83	4.9	7.4	3.1	16	1.71	1.35	3.02	(5)
84	4.9	7.4	3.1	22	2.56	1.56	2.69	(5)

Notes:
(1) Data from Table 2.1-2
(2) Approximate fraction of US-specification cars among sampled cars with labels.
(3) Ratio of Ontario basic rates (after elimination of excessive emitters in HC and CO) to US basic rates (at the same mileage levels, see L55).
(4) Based on OS 200 data (without EE cars)
(5) Based on WOS 295 data (no EE cars present)

It can be concluded that Ontario emission rates for 81-84 MY are substantially higher than rates calculated from U.S. data: by 70% - 155% in HC, by 35% - 75% in CO and possibly by up to 200% in NO_x. Consequently, Ontario emission factors (generated usually by MOBILE 2 or 3) should be significantly higher than U.S. factors.

10.4 FLEET C: Police & Gov't Cars

Results of the 52 high-mileage cars (tested in 1979-80) indicate very high correlations between weighted EPA data and phases of the MFTP (i.e. TBSTAB and TBHOT, see Table 9.3-4 above). Depending on pollutant and test phase, r is from 0.80 to 0.98; i.e. good to excellent.

Fleet C data (without 4 cars which had MFTP results missing) were then analyzed using four different models of multiple linear equations. Table 10.4-1 estimates model parameters and multiple correlation coefficients. R-SQUARE values are very high, from 0.78 to 0.99. Inclusion of MODELYR as a third variable (in addition to TBHOT and TBSTAB) does not improve R^2 significantly.

Table 10.4 - 1

Estimates of Model Parameters for Multiple Linear Regressions (1)
Fleet C (High-mileage police & government cars)

Model Year	N (Cars)	Y (Dependent) EPWEIG	Coefficients (1) a (for X_1= TBHOT)	b (for X_2= TBSTAB)	c (for X_3= MODELYR)	i Intercept	R^2 Multiple Correl. Coeff. (2)
74-79	48	HC	.103	.848	*	.656	.785
	48	CO	.330	.661	*	8.533	.903
	48	NO	.192	.795	*	.204	.927
	48	FC	-.046	.961	*	1.414	.972
74-79	48	HC	.313	.847	*	*	.959
	48	CO	.491	.680	*	*	.970
	48	NO	.244	.807	*	*	.985
	48	FC	-.029	1.019	*	*	.999
74-79	48	HC	.108	.842	.009	*	.966
	48	CO	.330	.658	.112	*	.978
	48	NO	.193	.795	.003	*	.986
	48	FC	-.048	.964	.018	*	.999
74-79	48	HC	.116	.832	.021	-.963	.785
	48	CO	.356	.634	1.359	-96.313	.908
	48	NO	.184	.796	-.025	2.122	.928
	48	FC	-.053	.977	.077	-4.704	.973

Notes: (1) Multiple linear equation: $Y = aX_1 + bX_2 + cX_3 + i$.
(2) R^2 (R-SQUARE) shows variation in the dependent variable (e.g., HCEPWEIG) accounted for by the model.
* Not used in this model.

Fleet C results were surveyed early in the test program (in 1980-81). They fulfilled the expectations by demonstrating very good relatability of MFTP-75 to FTP-75 procedure. Subsequently, the hot-start, 2-bag test (MFTP) became a permanent part of the dynamometer test procedure.

10.5 Other Test Data

10.5.1 Propane-powered cars

As shown in Table 9.4-3, the propane cars (# 225, 226) are on the average slightly higher in HC, lower in CO and significantly higher (more than 5 times) in NO_x than their gasoline-powered peers. (Note: Canada Motor Vehicle Safety Act exempts propane cars from compliance with emission standards. They are allowed to operate in Canada without the principal emission controls - CAT, AIR, EGR - and their NO_x emissions are usually in the 6 to 9 g/mi range, see L54).

While car #226 is very low in CO (2.74 g/mi), car #225 emits 11.75 g/mi and is within the range of comparable gasoline cars, i.e. between 10.7 and 18.2 g/mi, see Table 9.4-2, above. It seems that in the case of car #225, propane's potential for low emissions is not utilized completely.

10.5.2 Retests of cars

Tables 9.4-4 and -5, demonstrate the variability of test results with time. While three cars (# 157, 266, 342) show little change in HC and CO, the remaining 2 cars show increases from 11% to 80%. Changes in NO_x range from -11% to +37%.

Table 10.5-1 presents statistics for all 5 cars and for smaller sub-groups after elimination of car #245 (retest after over 5 months with major increase in CO) or car #224 (missing NO_x) or both. Arith. means of test groups with 5 and 4 cars show increases in HC and CO and a decrease in NO_x. (Note: Extrapolation of results, e.g. to find deterioration over 1 year, should not be attempted, as sample of 5 cars is too small and average periods between base tests and retests are too short).

Table 10.5-1

Retests of 5 cars - Simple Statistics

Pollutant	Test Group	Sub-test	Simple Statistics		
			Arith. Mean g/mi	S.D. g/mi	C.V.
HC	5 cars (all)	0	9.29	13.43	144.6
		1	10.32	14.98	145.2
		% dif.	+11.1	-	-
	4 cars (w/o #245)	0	3.38	2.71	80.2
		1	3.74	3.23	86.4
		% dif.	+10.7	-	-
CO	5 cars (all)	0	43.81	24.52	56.0
		1	59.27	48.40	81.7
		% dif.	+35.3	-	-
	4 cars (w/o #245)	0	35.73	19.16	53.6
		1	39.90	24.92	62.5
		% dif.	+11.7	-	-
NO_x	5 cars (all)	0	N/A	N/A	N/A
		1			
	4 cars (w/o #224)	0	3.05	.49	16.1
		1	2.84	1.01	35.6
		% dif.	-6.9	-	-
	3 cars (w/o #224, #245)	0	2.86	.38	13.3
		1	3.03	1.15	38.0
		% dif.	+5.9	-	-

S.D. Standard Deviation

C.V. Coefficient of variation = $\frac{\text{S.D. x 100}}{\text{Mean}}$

% dif. Difference (in % rel.) between subtest 0 and 1.

Results of individual cars also indicate the possible impact of changes in scheduling of tests on the emissions. One can argue that had the testing (= base test) of a certain car in WOS 295 been postponed, then different emissions (likely higher in HC and CO) would have been recorded as representative. By the same token, the testing of some other car would have been performed earlier to maintain the regular supply of test cars.

11.0 CONCLUSIONS AND RECOMMENDATIONS

11.1 Conclusions

Results of the exhaust emission surveillance program summarized in this report reveal that:

1. Samples of Ontario cars show a general trend to higher HC, CO and NO_x emissions and to higher fuel consumption with older models. There is a correlation of HC with CO, which for newer models (75/84 subgroup) is very good, $r = 0.87$. Correlations of NO_x with HC or with CO are either unacceptable or nonexistent.

2. Almost half (48%) of OS 200 cars fail one or more of the four Ontario Idles criteria for HC and CO.

3. Almost three quarters (74%) of OS 200 cars fail one or more of the three Canada standards (or equivalents) for HC, CO and NO_x. One car in six (17%) fails all three standards. Fail rates are higher for subgroups of older MY.

4. Current Ontario Idles Test (under Reg. 311, RRO 1980) is an excellent tool for predicting compliance with Canada HC and CO standards: 74% of WOS 295 cars are correctly passed or correctly failed. Error of omission E_o is 22%, error of commission E_c is only 4%. As expected the Idles Test (HC, CO) is not relevant to Canada NO_x standard.

5. Ontario samples show the presence of 7-9% of excessive emitters (EE). Their frequency is being underestimated due to the built-in bias in sampling. EE cars in actual Ontario population are estimated at 15% to 20%.

6. EE cars emit in the average 6x more HC and 4x more CO than the other, non-excessive (NE) cars.

7. Some EE cars are of recent MY and highly controlled; e.g. the highest car in CO is a 1980 Ford with CAT and AIR. It exceeds Canada CO standard 10x, and HC standard 13x. The highest car in HC is a 1968 Plymouth which exceeds the present HC standard (2.0 gpm) 30 times.

7. Some EE cars are of recent MY and highly controlled; e.g., the highest car in CO is a 1980 Ford with CAT and AIR. It exceeds Canada CO standard 10x, and HC standard 13x. The highest car in HC is a 1968 Plymouth which exceeds the present HC standard (2.0 gpm) 30 times.

8. Ontario Idles Test is very successful in identifying EE cars: 90% are identified by analysis of gaseous pollutants (HC, CO) and 95% are identified, if visual observation for black smoke is added.

9. EE cars are a significant source of pollution: the estimated 15% are likely responsible for 51% of HC and 41% of CO from all cars.

10. A simple control program (inspection/maintenance), aimed at EE cars alone, is expected to reduce HC emissions from the whole population by 27% and CO by 16%. (Further reductions will follow from control of identified high emitters in the NE group.)

11. Mean emissions of cars vary with manufacturers. In the 75/79 subgroup, Chrysler products are slightly higher than the other 3 major manufacturers.

12. US-specification cars are not achieving their full low-emission potential, possibly due to faster deterioration.

13. Correlations of the shorter MFTP (hot-start, 2-bag test) with FTP-75 are very high. For the newer models (75/84 subgroup) R^2 are 0.91 to 0.93, depending on pollutant. Best correlations are for fuel consumption FC.

14. Correlations of MFTP with FTP for individual MY groups are also very high. Additional variables (INERTIA, CID, MILEAGE) improve R^2 only very slightly.

15. Estimated Ontario emission rates (for 1981-84 MY) are substantially higher than rates based on U.S. data: by 70-155% in HC, by 35-75% in CO and up by up to 200% in NO_x.

16. Propane cars (2), while showing a potential for low CO and HC emissions, are more than 5x higher in NO_x than comparable gasoline vehicles. Present canadian NO_x standard is exceeded 2.5 times.

11.2 General Outlook

- The emission and fuel economy test facility at Downsview, which has been operated jointly by MTC and MOE over the past six years, provides MOE with a unique investigative and research tool. A substantial data base of 374 in-use vehicles has been created and is discussed in this report. Further evaluation of this ever-growing data base should continue (e.g. involving other qualities and trends, and including results of additional 140 cars).

- The emission levels of Ontario car population will continue to be significantly different from U.S. cars until approx. 1996 (mainly as a result of lenient Canadian standards for 1975/87 MY). This precludes the use of U.S. emission factors in Ontario inventories. An updated representative sample of Ontario car population (similar to OS 200 for mid-1982) should be tested every 3 years.

- Excessive emitters (estimated at over 15% of all cars in Ontario) greatly contribute to HC and CO emissions. Investigations into their frequency and emission levels should continue.

- Should an inspection/maintenance program (I/M, based on emission criteria in Reg. 311, RRO 1980) be required in Ontario, the test facility could be used to investigate expected and later on actual reductions in HC, CO and NO_x mass-emissions.

- The catalytic converters, currently used on approx. 62% of Ontario cars, are highly sensitive to tampering and misfuelling (i.e. use of leaded gasoline). By 1996 an estimated 95% of cars will be catalyst equipped. Their natural (by age) and deliberate (by fuel switching) deactivation should be investigated in more detail.

- The Ontario government is promoting the use of alternate fuel vehicles. Research programs conducted by MTC focus on their driveability problems and on fuel economy. Evaluation of their exhaust emission levels, with emphasis on NO_x, is within the MOE mandate and should be expanded.

- Particulates from LD combustion engines (diesel and gasoline) are known to contain polycyclic aromatic hydrocarbons (PAH) which may cause or promote cancer. Providing that additional space and equipment would be attached to the existing test facility, the MOE research objectives could be expanded into this area.

11.3 Recommendations

(a) MOE testing capacity at Downsview Test Centre should be supported and used over the next years to:

- continue with the emission surveillance of in-use cars;
- enlarge data base for Ontario emission factors;
- investigate excessive emitters and their contribution to total emissions from LD vehicles;
- explore deactivation of catalytic control systems;
- establish deterioration in emissions (by retesting cars after 3-5 years);
- study emissions from alternate fuel vehicles (propane, CNG).

(b) Possibilities to expand and upgrade the test facilities, and to modify the current cold-start test procedure should be investigated in order to:

- enable sampling and research into particulates and toxic compounds from LD vehicles;
- partially substitute MFTP for FTP;
- increase the number of cars tested per year.

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- Photographs of testing facility and equipment on pages 49, 50 and 53 are courtesy of MTC, Graphic Services Section.

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